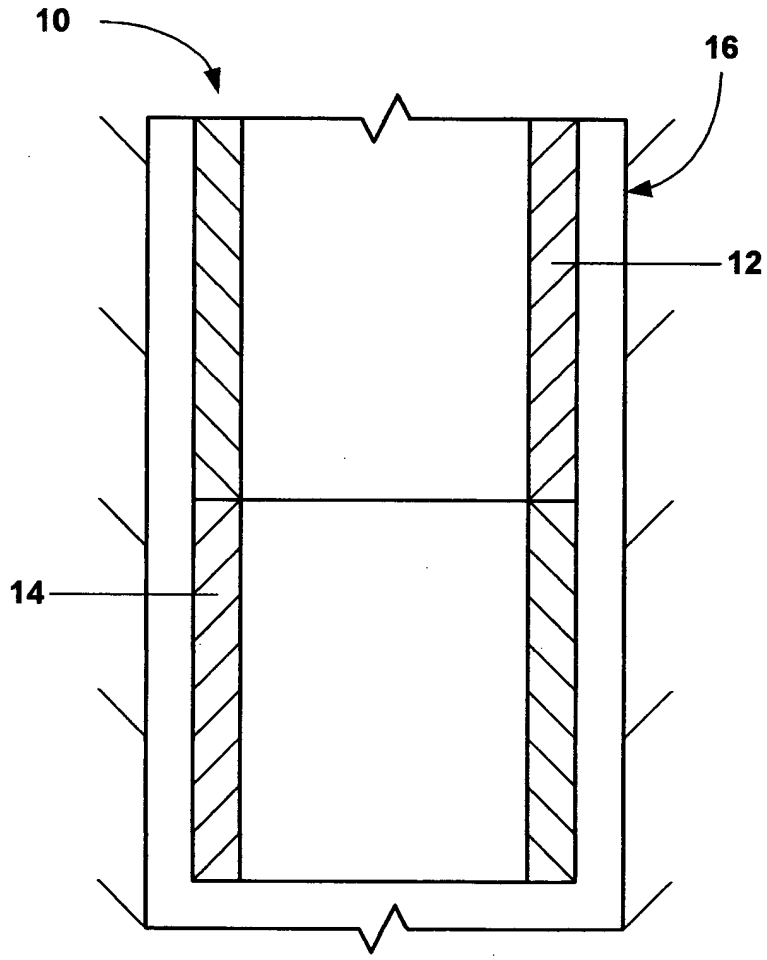


FIG. 1

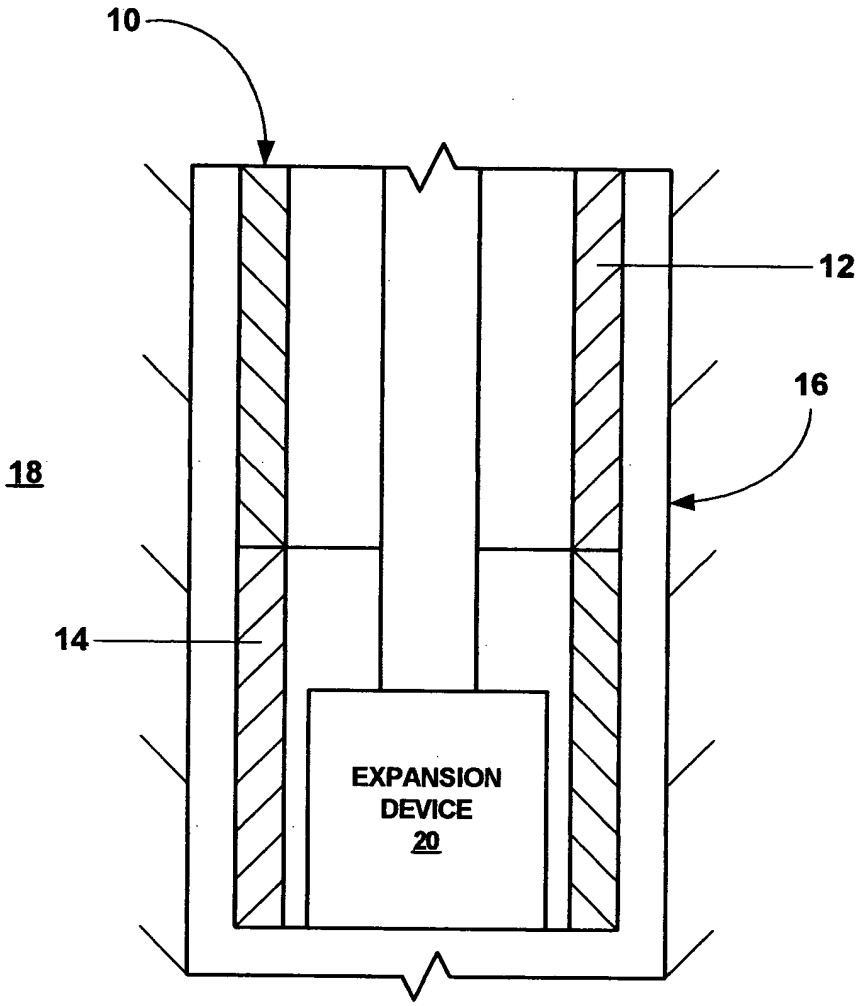


FIG. 2

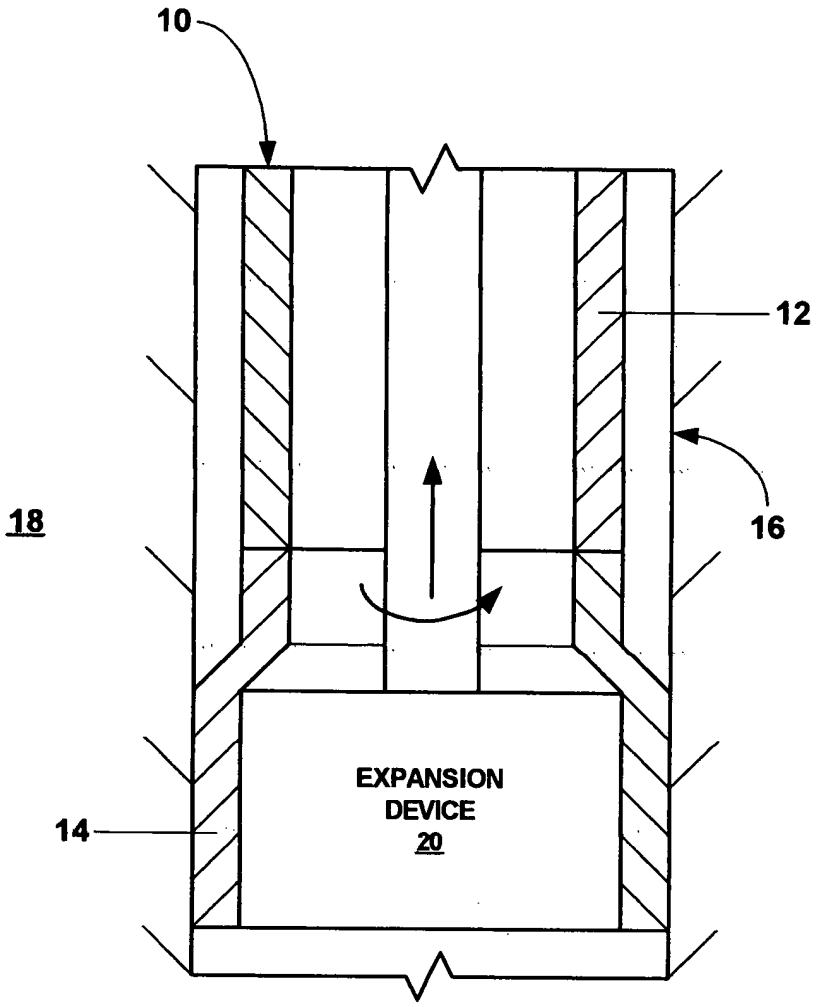


FIG. 3

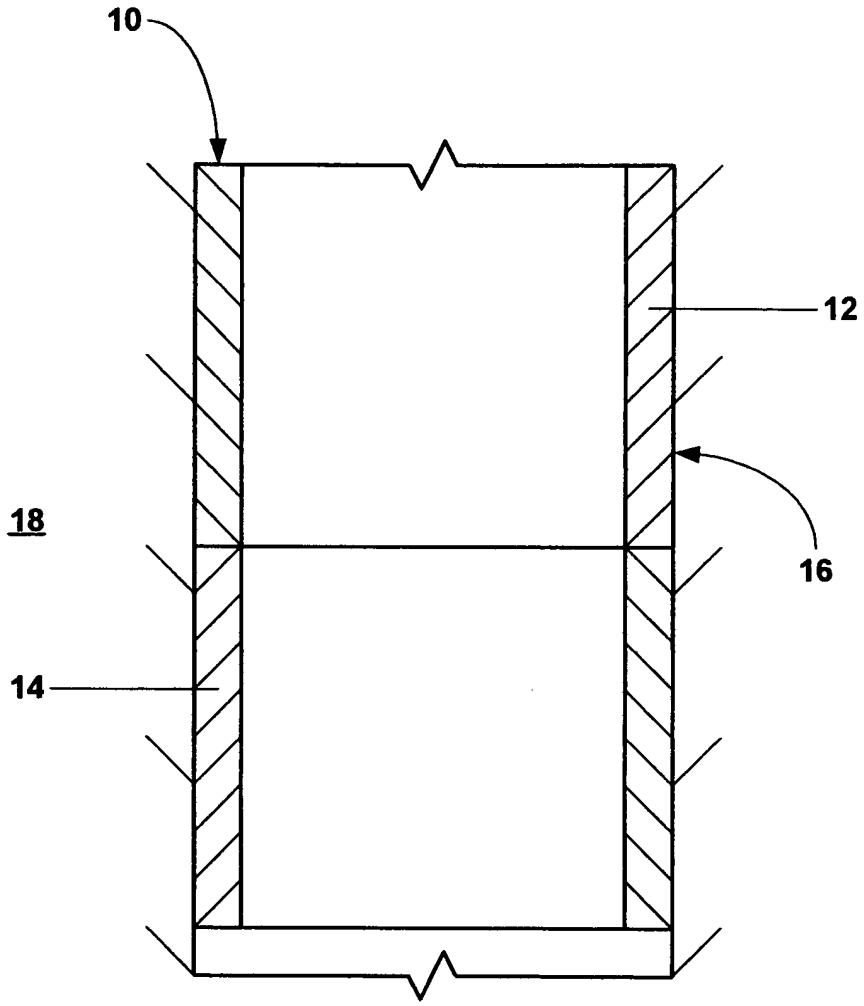


FIG. 4

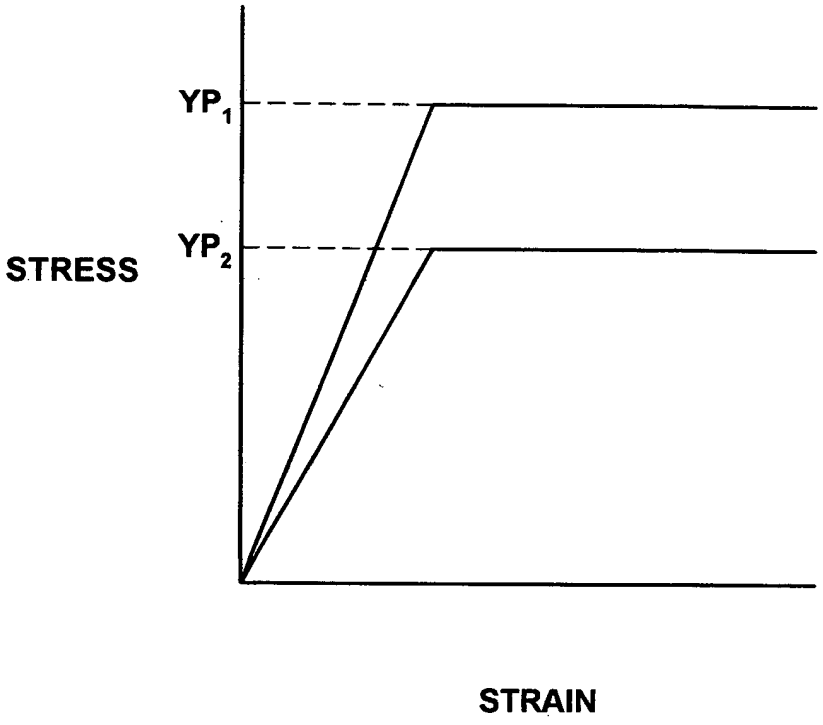

YP1
YP2
STRESS
STRAIN

FIG. 5

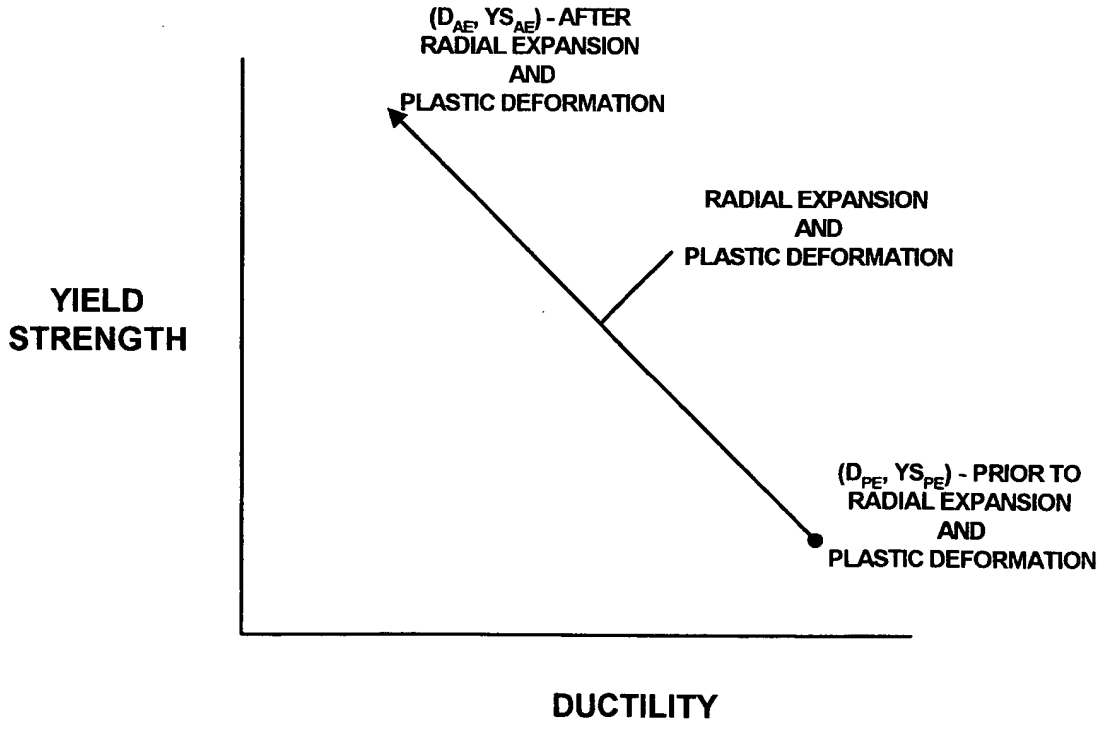

(DAE, YSAE) - AFTER RADIAL EXPANSION AND PLASTIC DEFORMATION
RADIAL EXPANSION AND PLASTIC DEFORMATION
(DPE, YSPE) - PRIOR TO RADIAL EXPANSION AND PLASTIC DEFORMATION
YIELD STRENGTH
DUCTILITY

FIG. 6

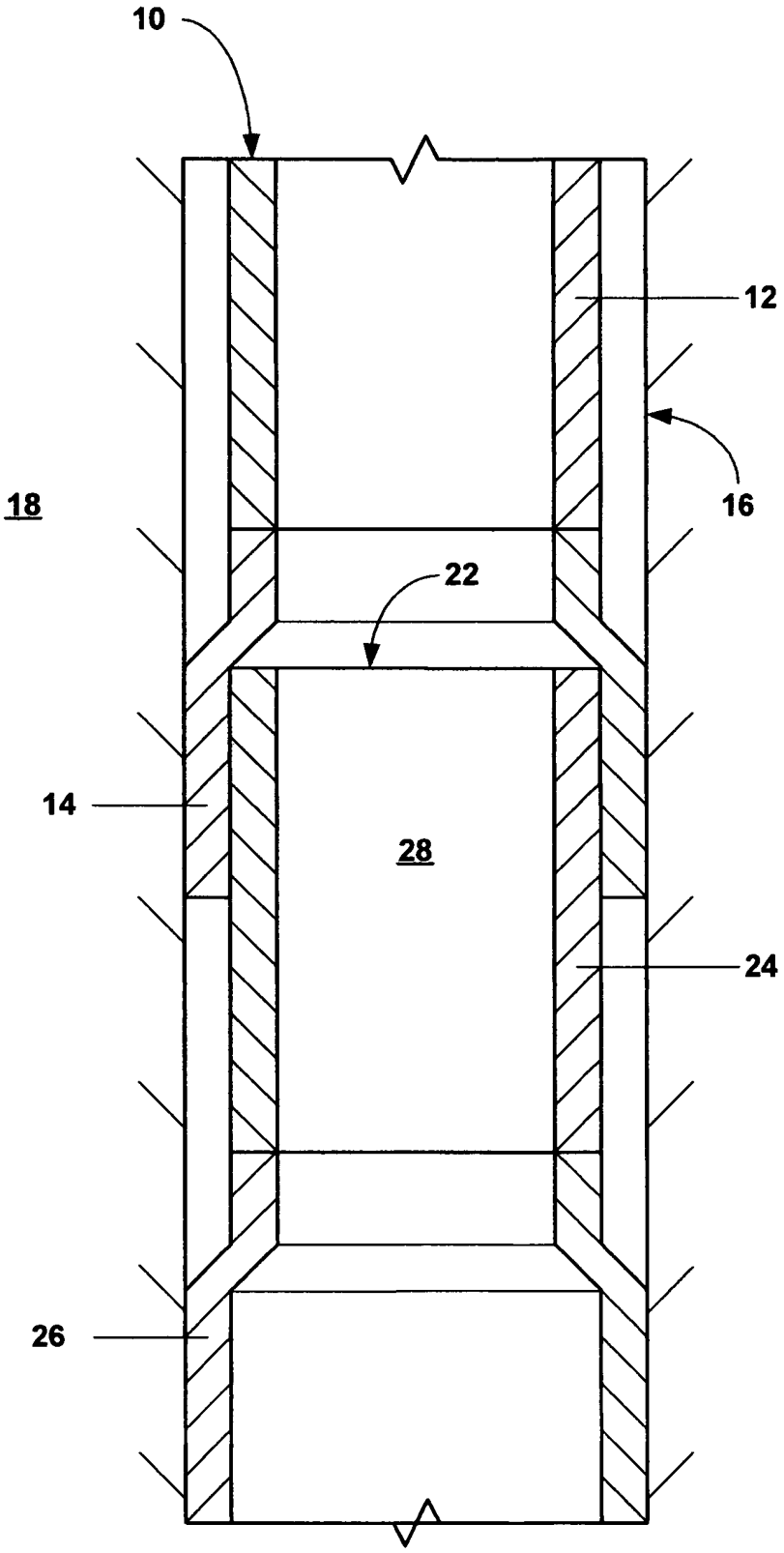


FIG. 7

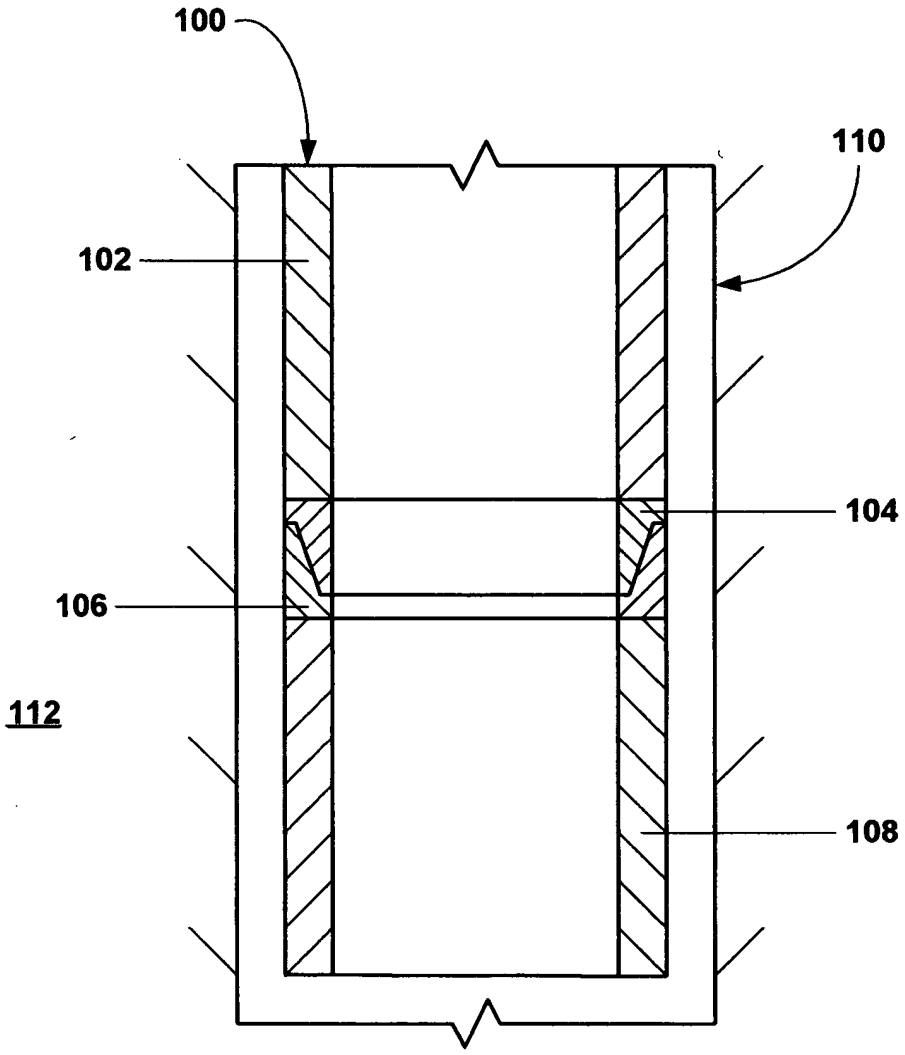


FIG. 8

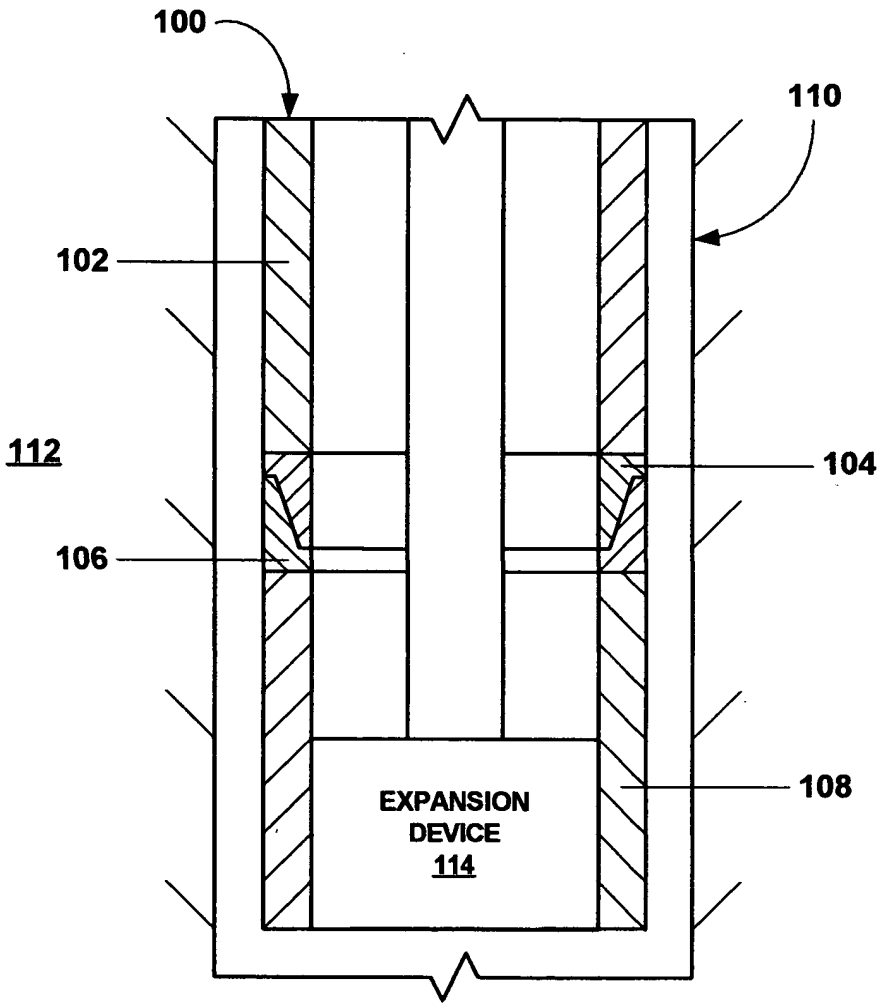


FIG. 9

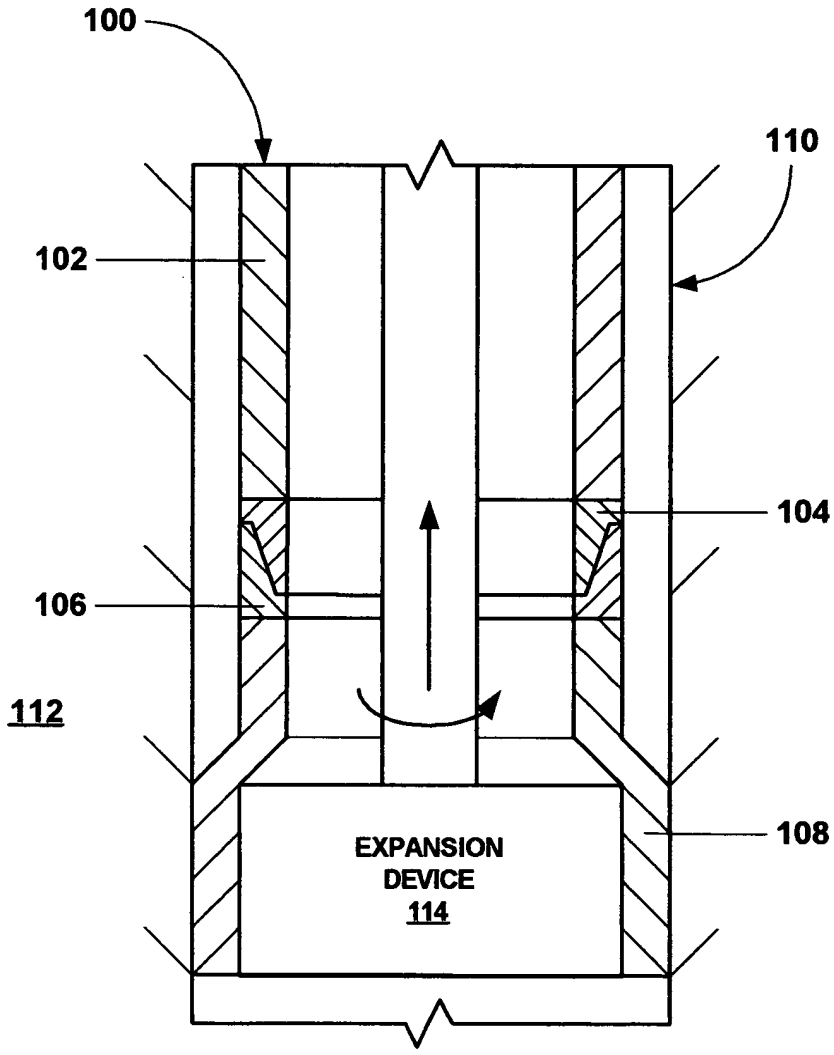


FIG. 10

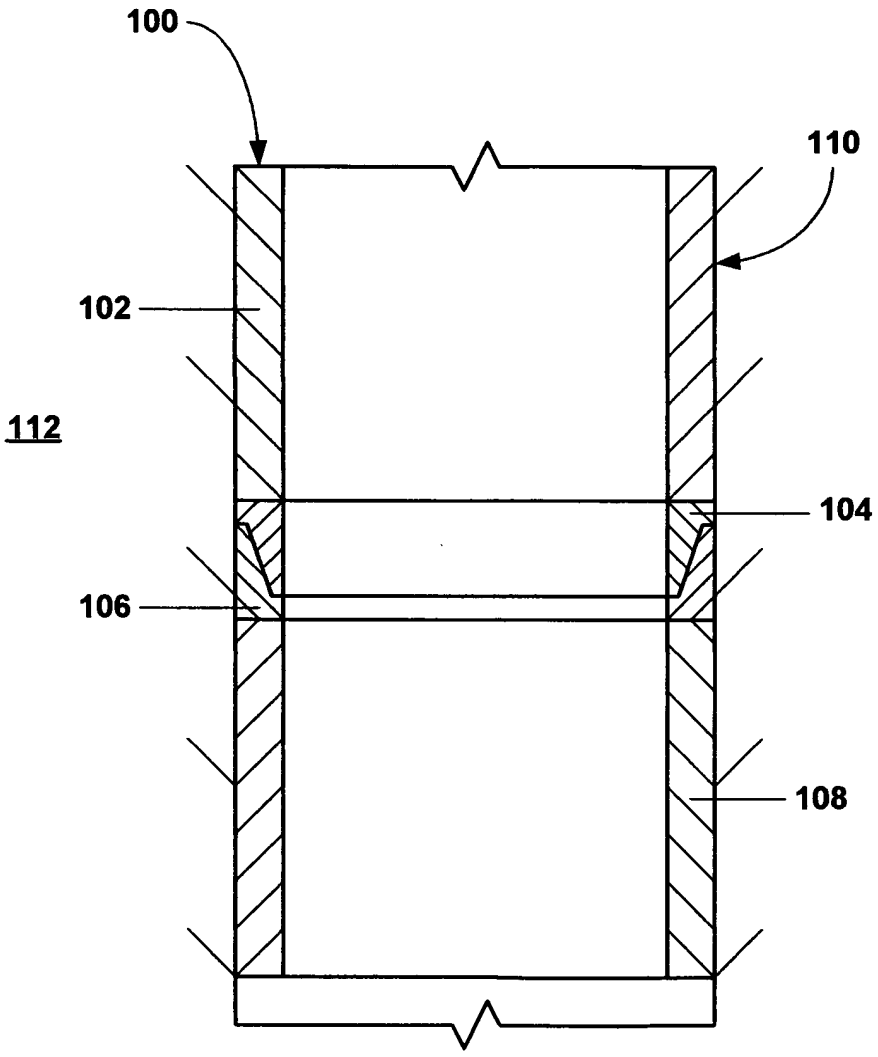


FIG. 11

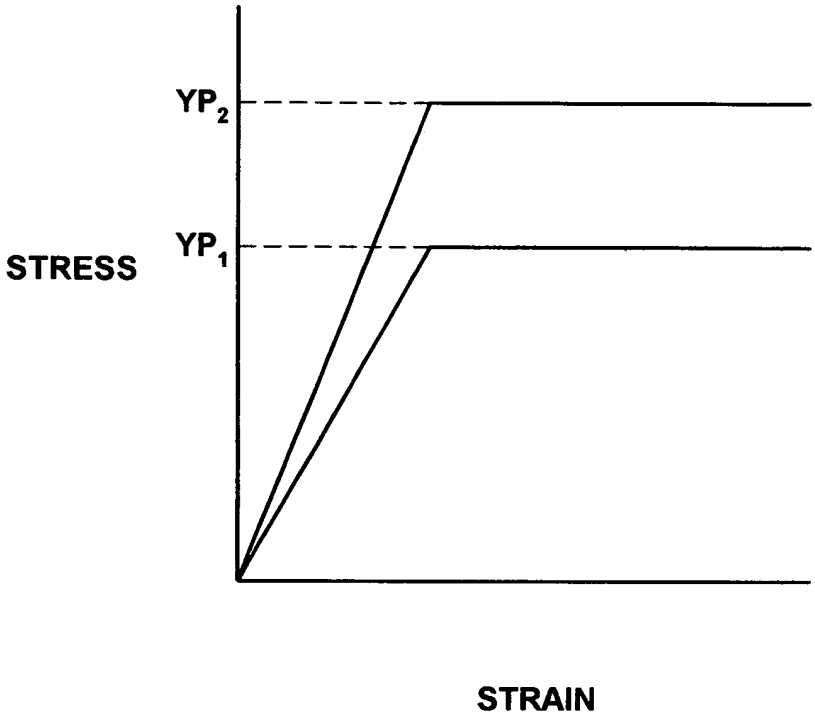

YP2
YP1
STRESS
STRAIN

FIG. 12

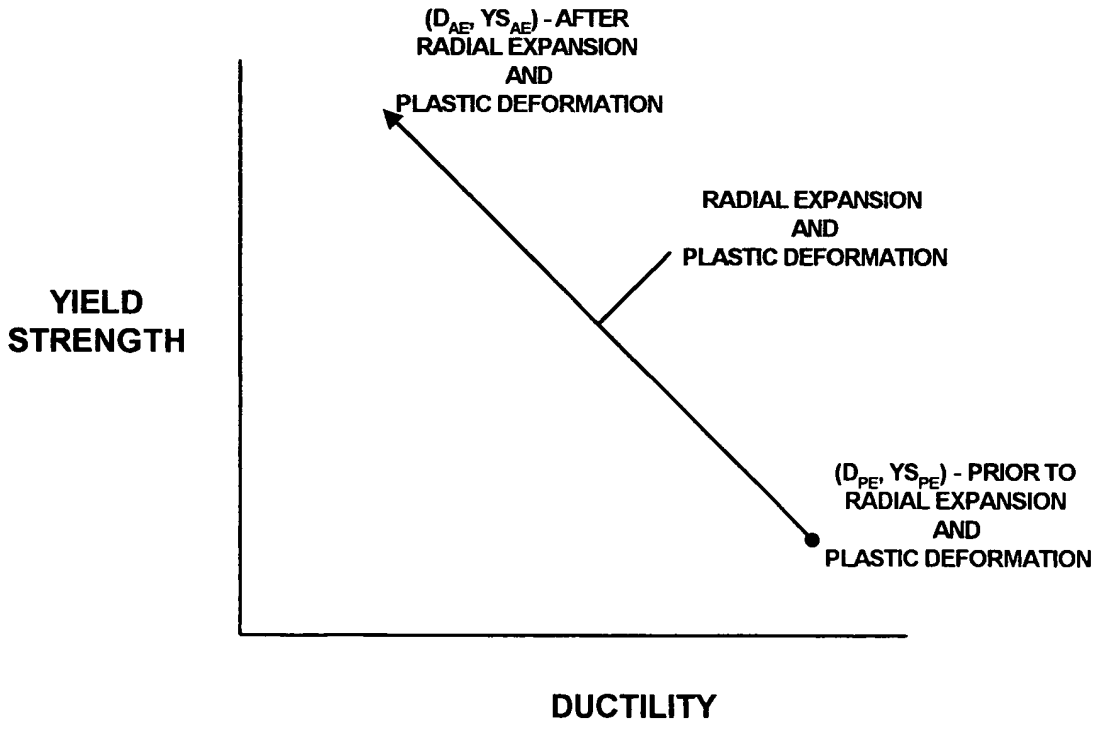

(DAE, YSAE) - AFTER RADIAL EXPANSION AND PLASTIC DEFORMATION
RADIAL EXPANSION AND PLASTIC DEFORMATION
(DPE, YSPE) - PRIOR TO RADIAL EXPANSION AND PLASTIC DEFORMATION
YIELD STRENGTH
DUCTILITY

FIG. 13

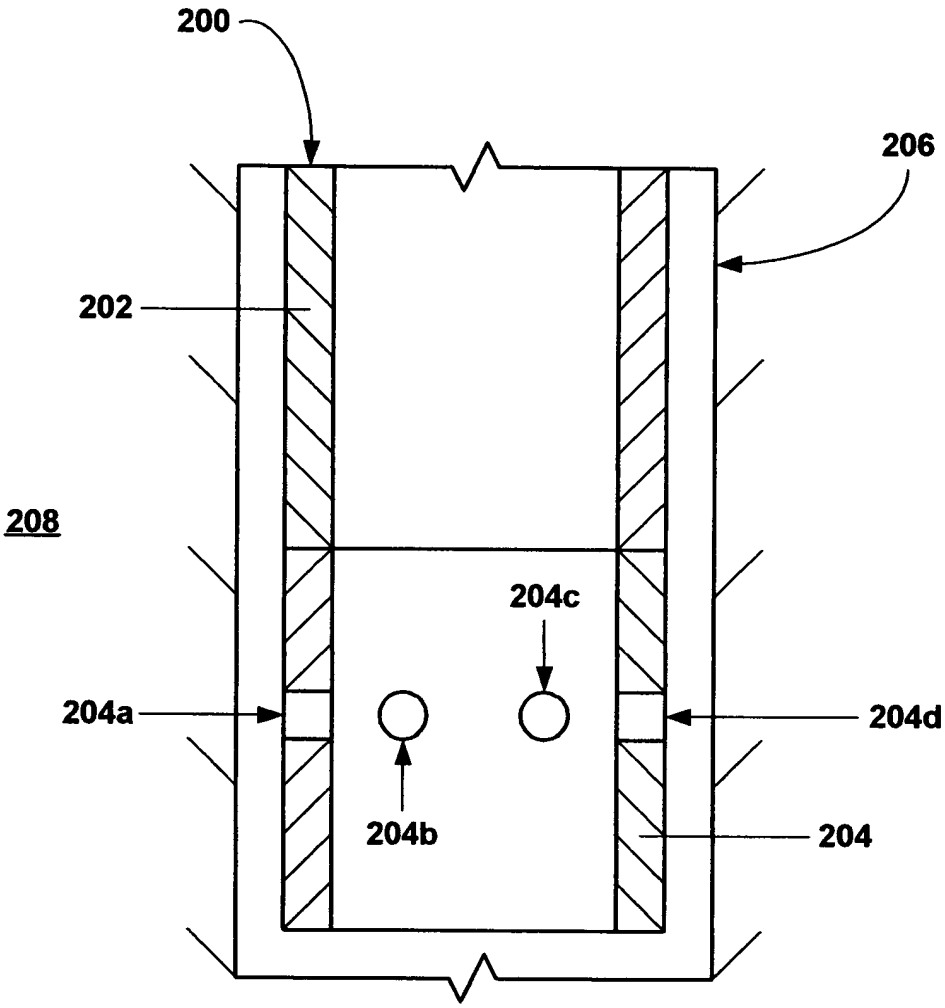


FIG. 14

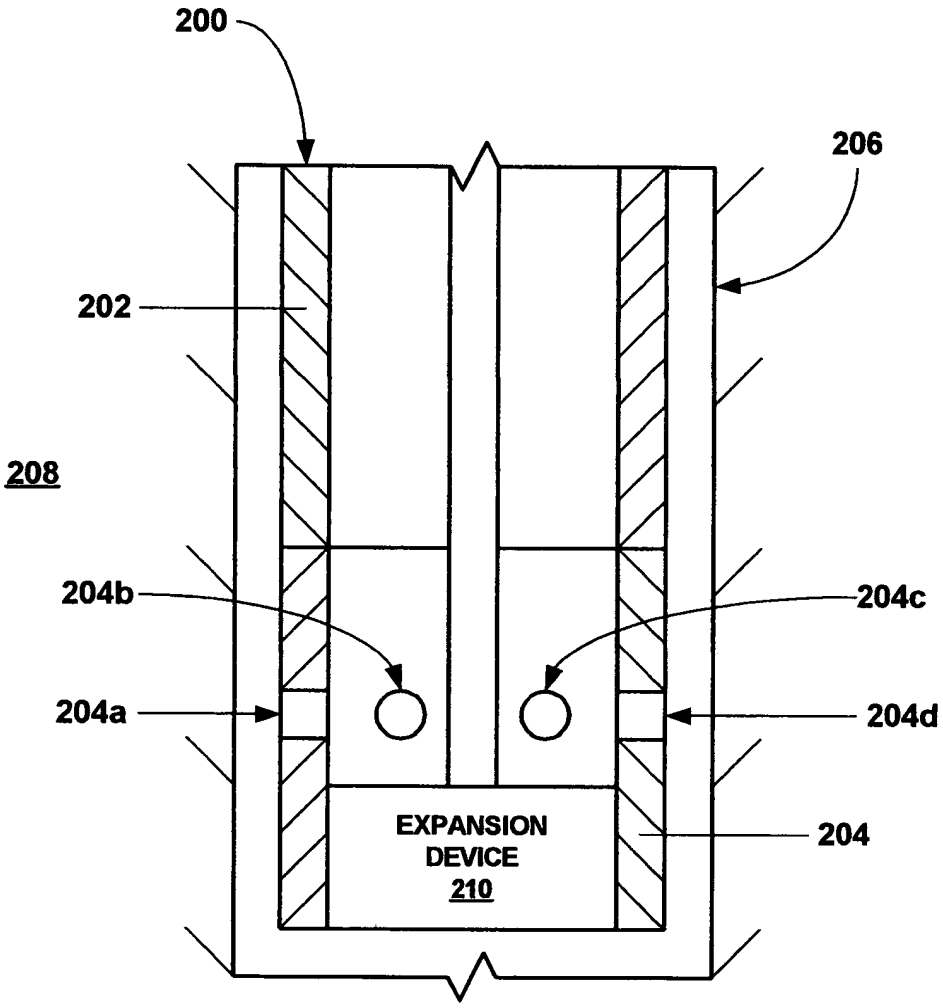


FIG. 15

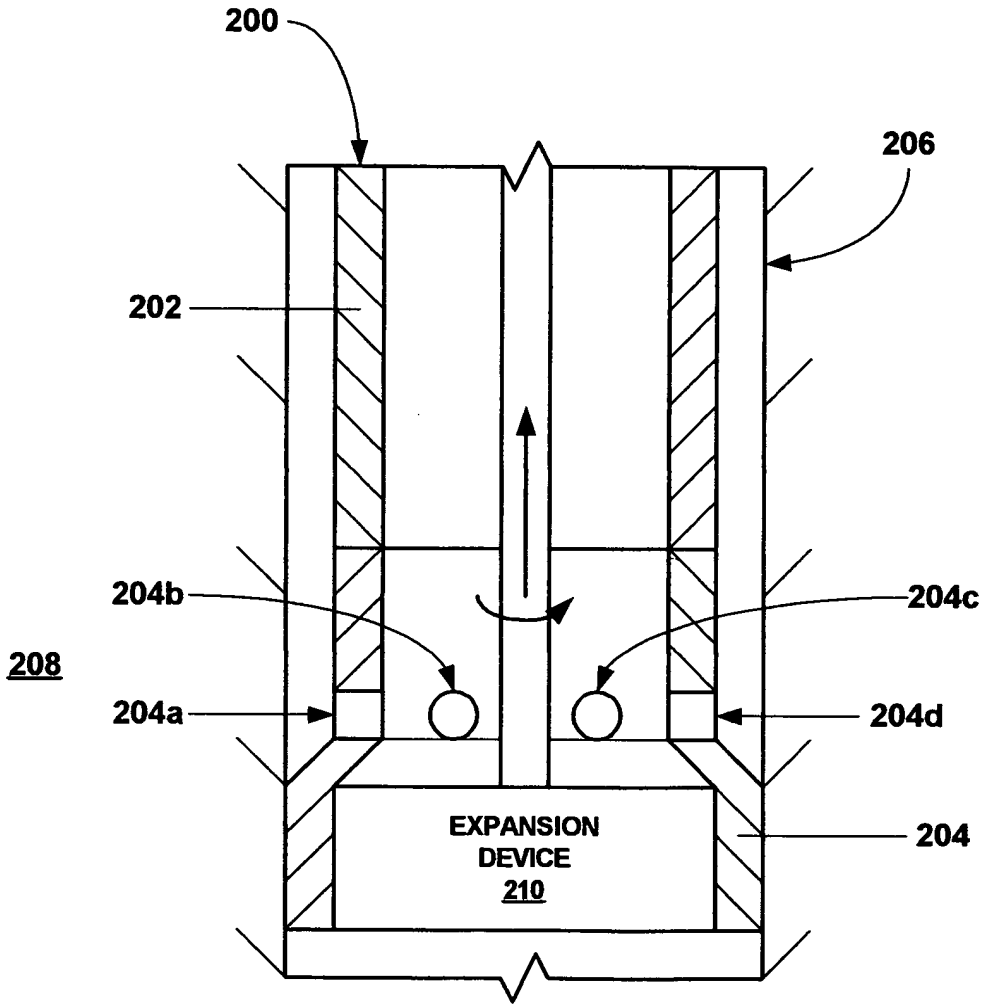


FIG. 16

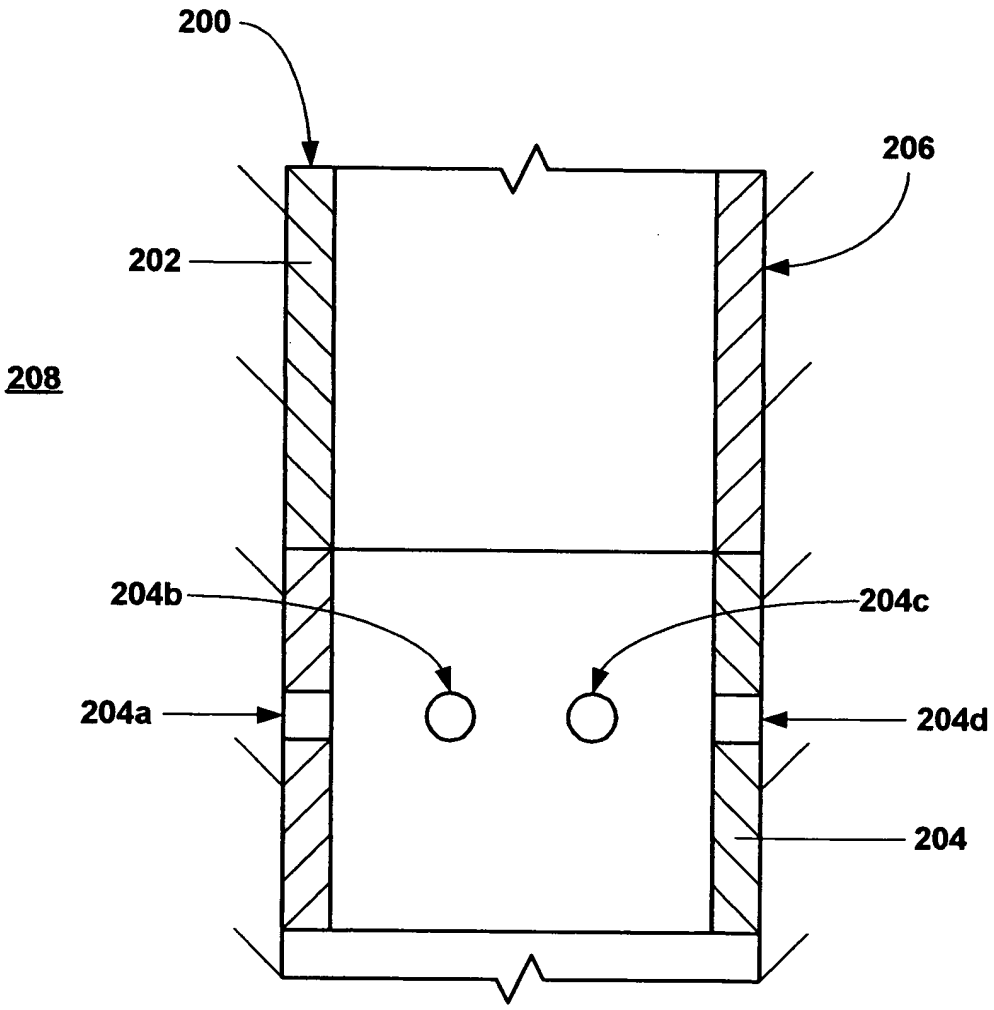


FIG. 17

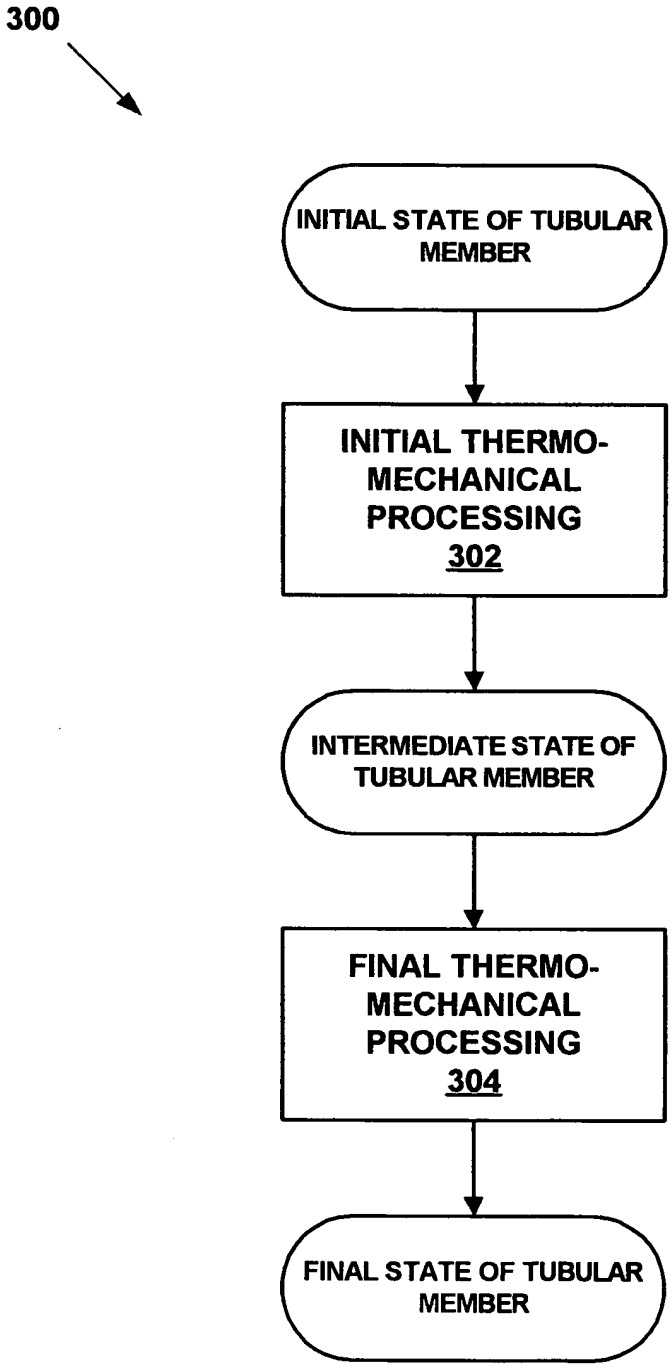

300
INITIAL STATE OF TUBULAR MEMBER
INITIAL THERMO-MECHANICAL PROCESSING
302
INTERMEDIATE STATE OF TUBULAR MEMBER
FINAL THERMO-MECHANICAL PROCESSING
304
FINAL STATE OF TUBULAR MEMBER

Fig. 18

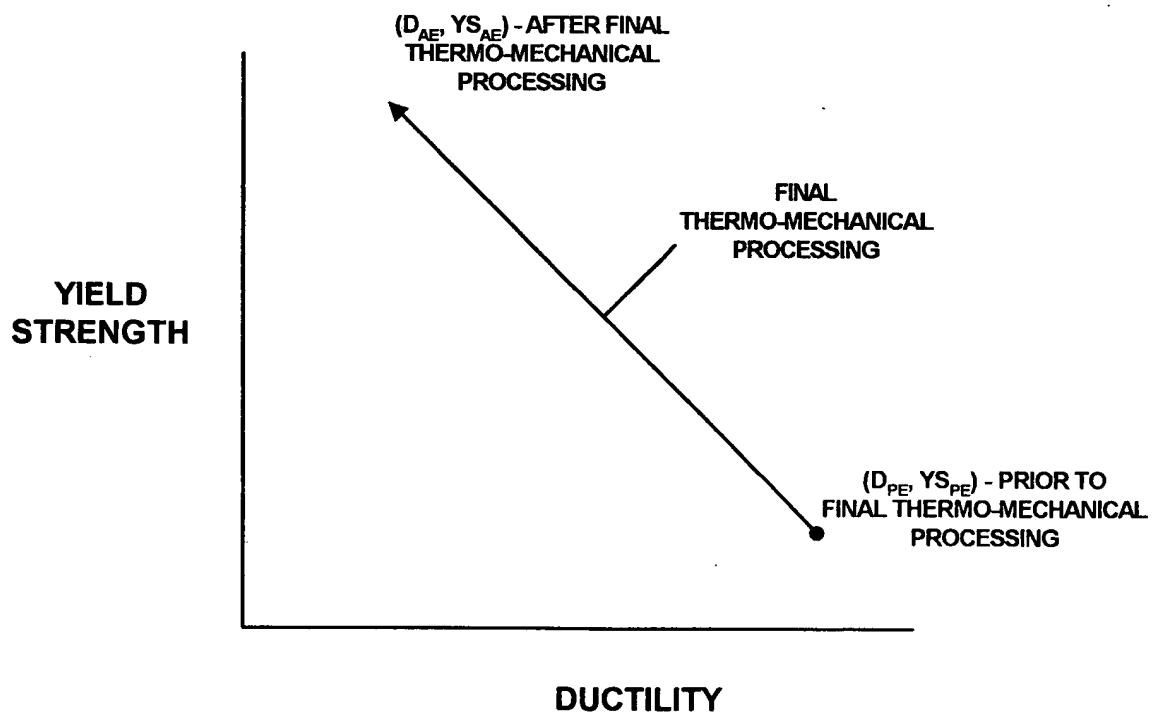

(D_{AE}, YS_{AE}) - AFTER FINAL THERMO-MECHANICAL PROCESSING
FINAL THERMO-MECHANICAL PROCESSING
(D_{PE}, YS_{PE}) - PRIOR TO FINAL THERMO-MECHANICAL PROCESSING
YIELD STRENGTH
DUCTILITY

FIG. 19

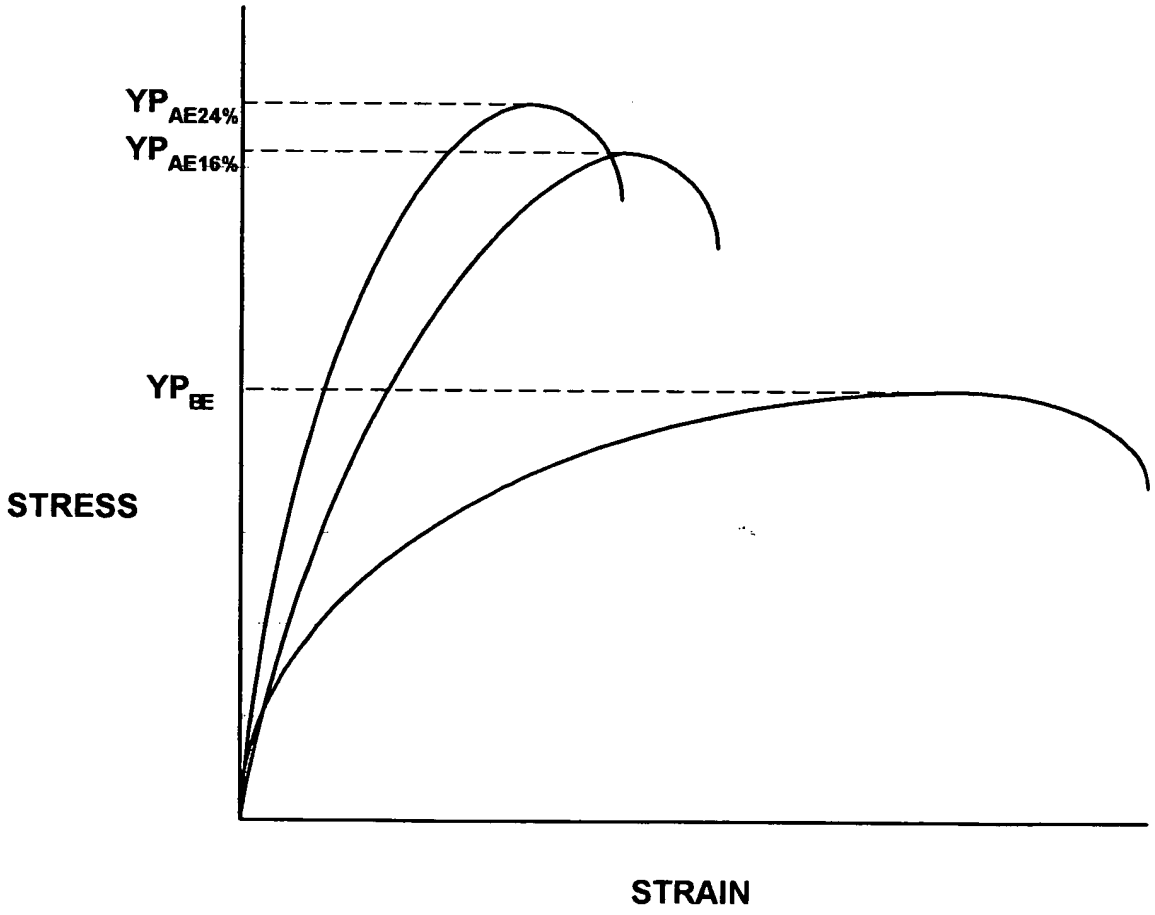


FIG. 20

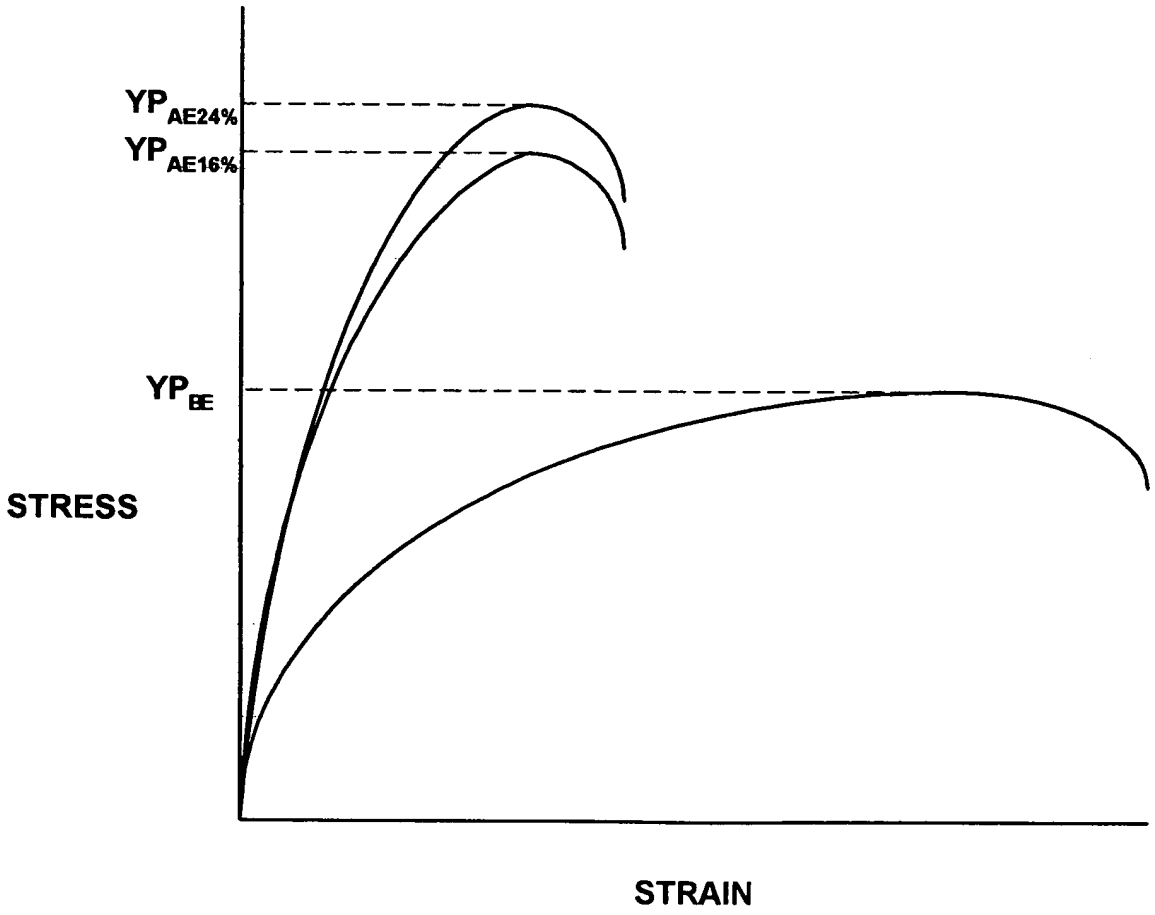


FIG. 21

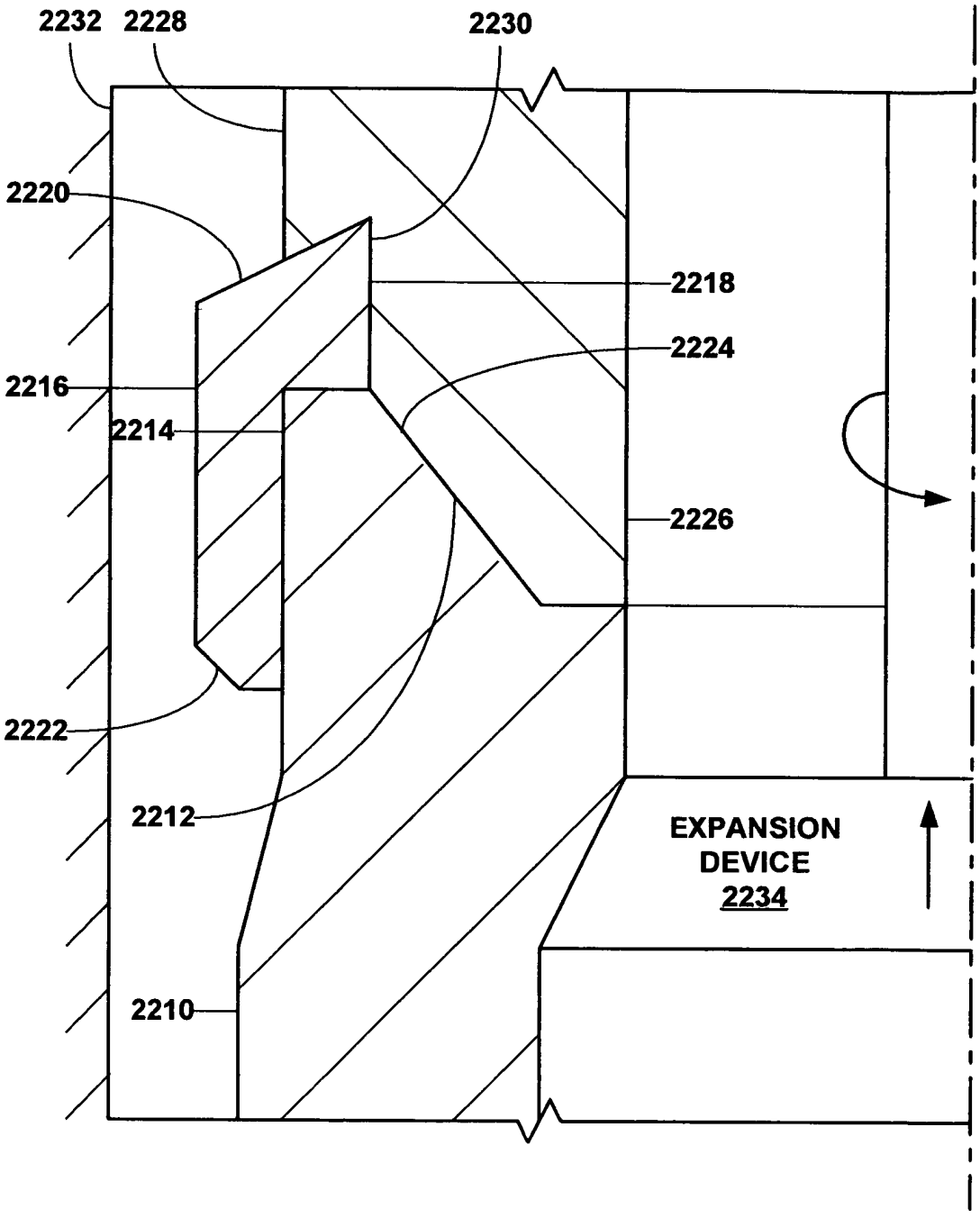

2232
2228
2230
2220
2218
2224
2216
2214
2226
2222
2212
EXPANSION
DEVICE
2234
2210

FIG. 22

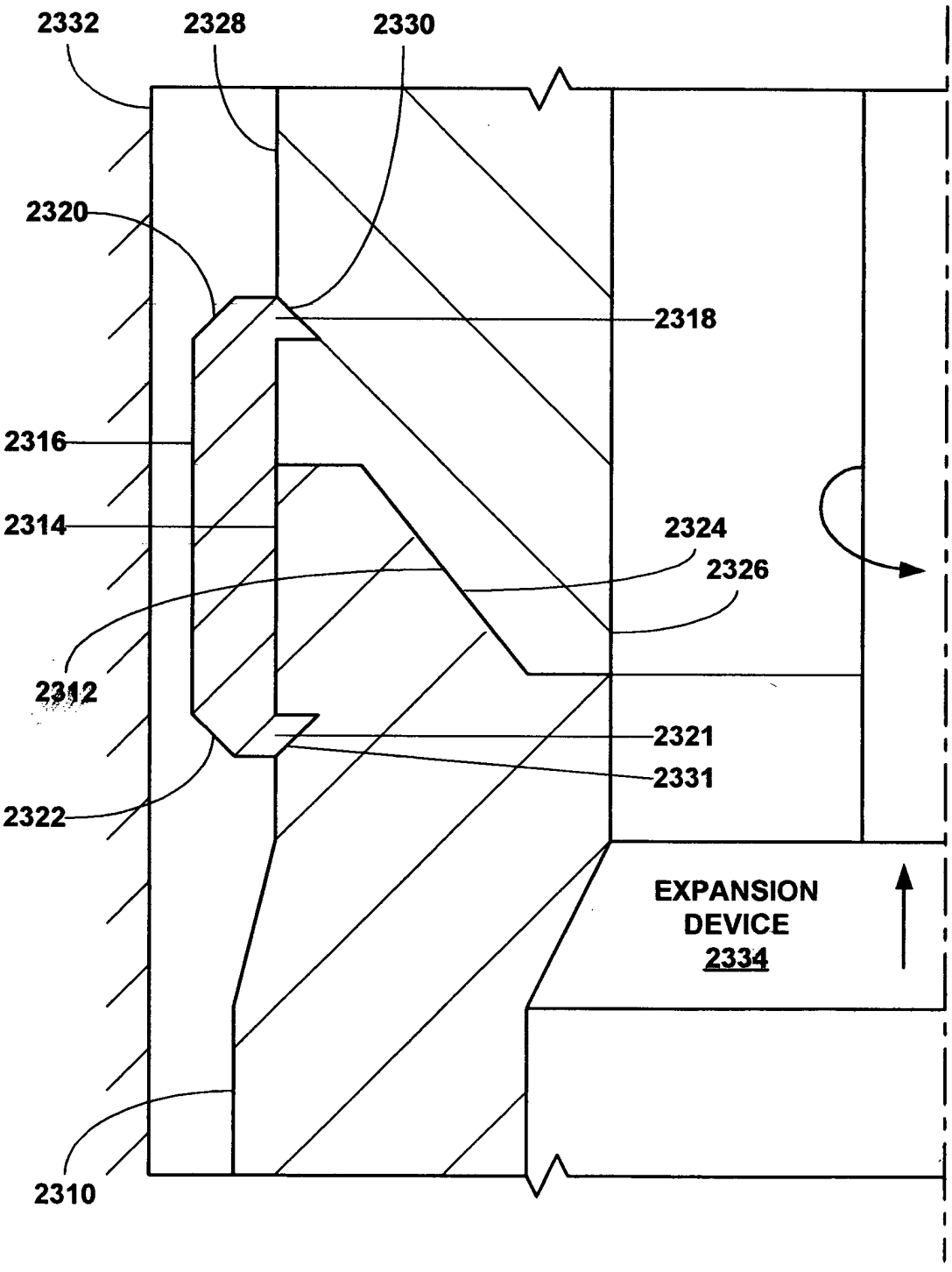

2332
2328
2330
2320
2318
2316
2314
2324
2326
2312
2321
2331
2322
EXPANSION
DEVICE
2334
2310

FIG. 23

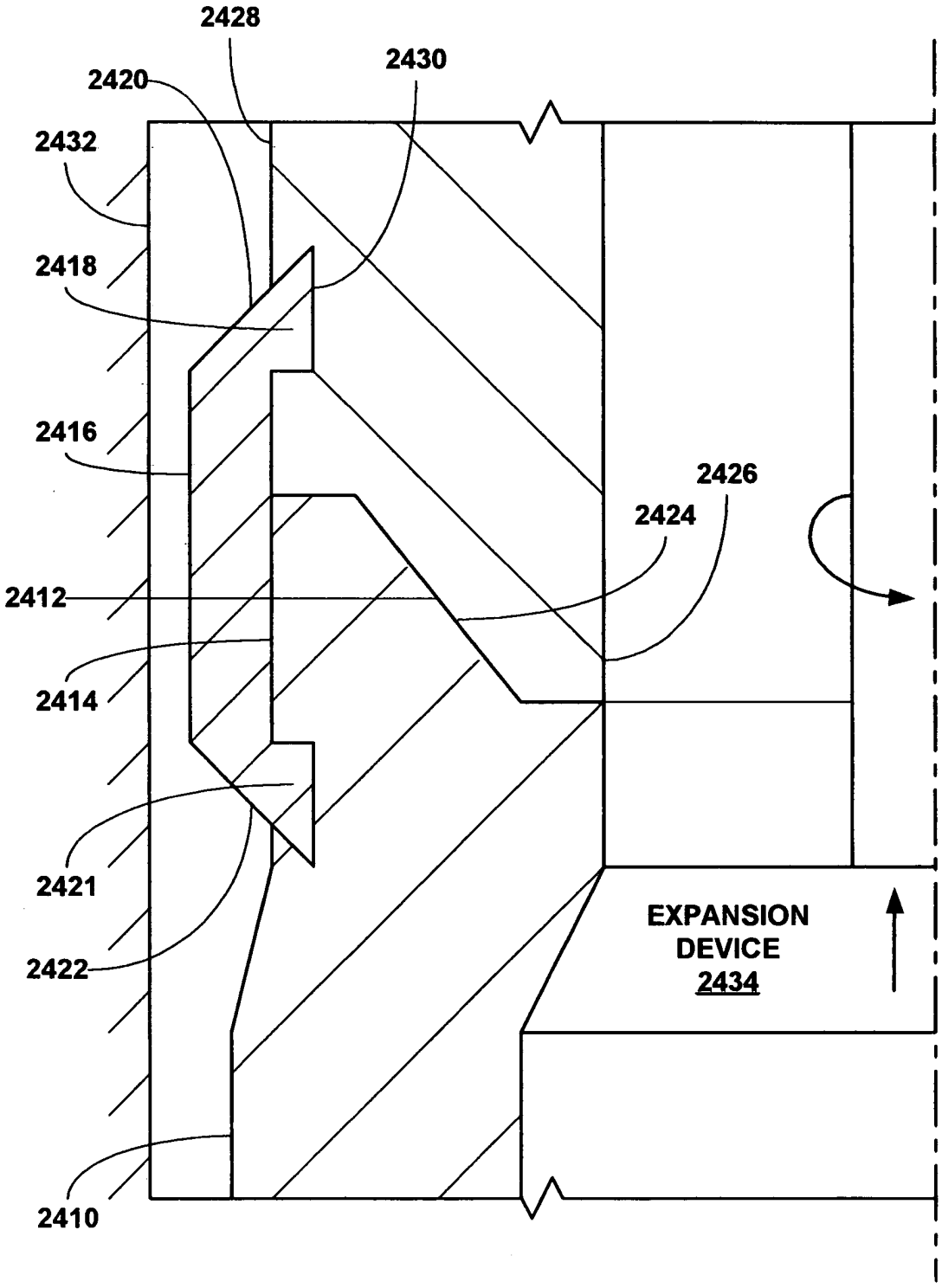

2428
2430
2420
2432
2418
2416
2426
2424
2412
2414
2421
2422
EXPANSION
DEVICE
2434
2410

FIG. 24

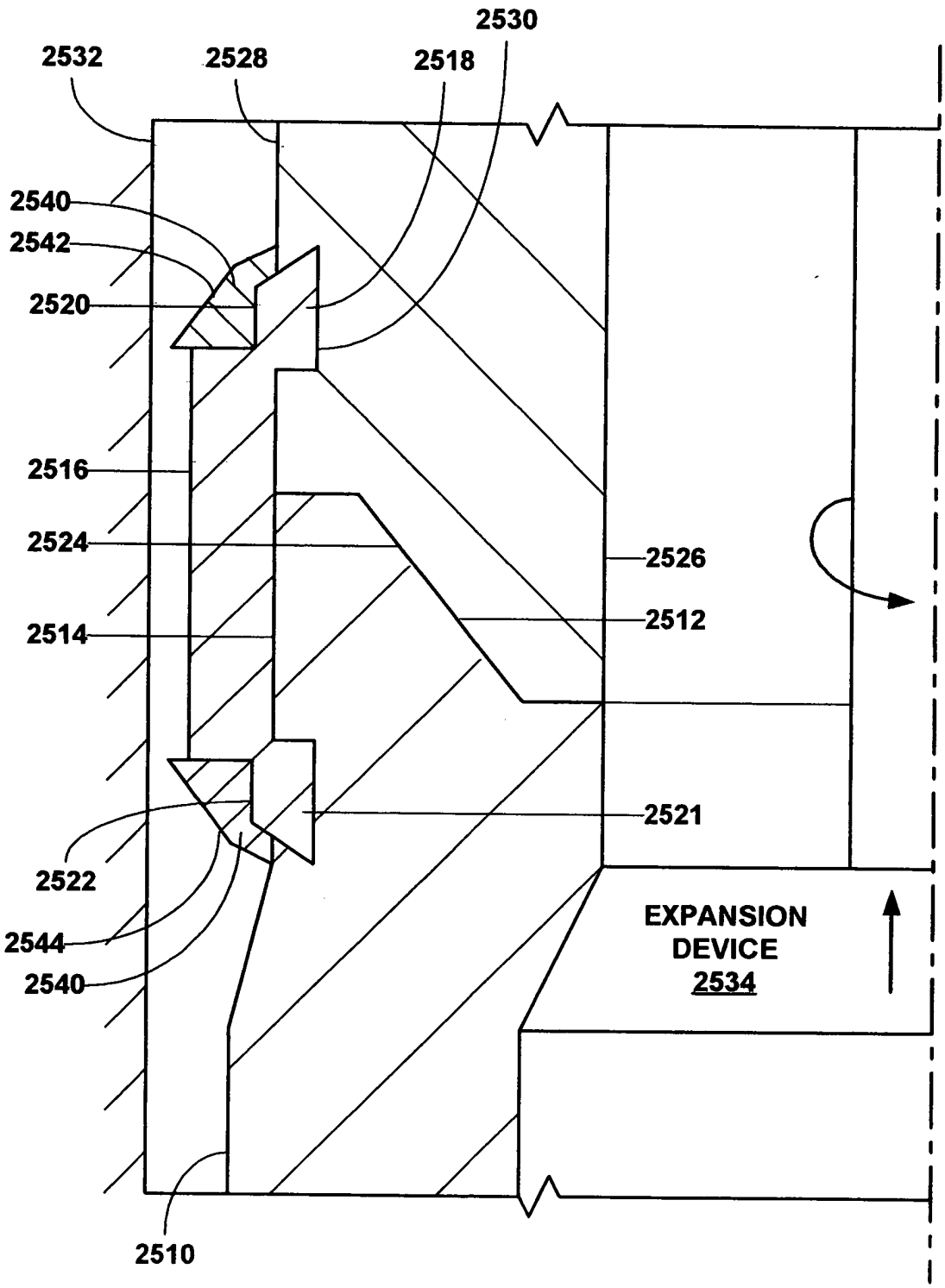
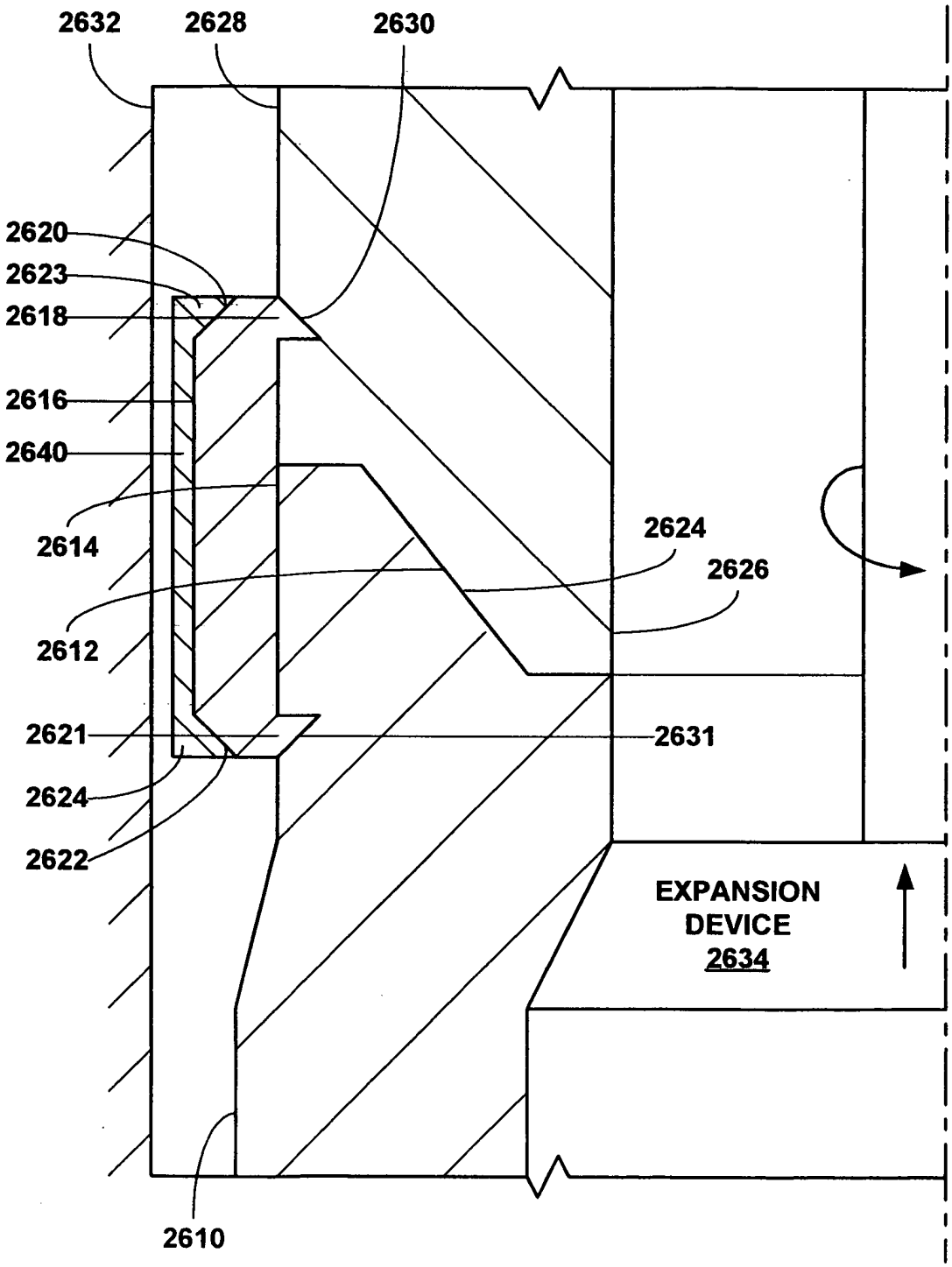

2530
2532
2528
2518
2540
2542
2520
2516
2524
2526
2514
2512
2521
2522
2544
2540
EXPANSION
DEVICE
2534
2510

FIG. 25


2632
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2620
2623
2618
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2640
2614
2624
2626
2612
2621
2631
2624
2622
EXPANSION
DEVICE
2634
2610

FIG. 26

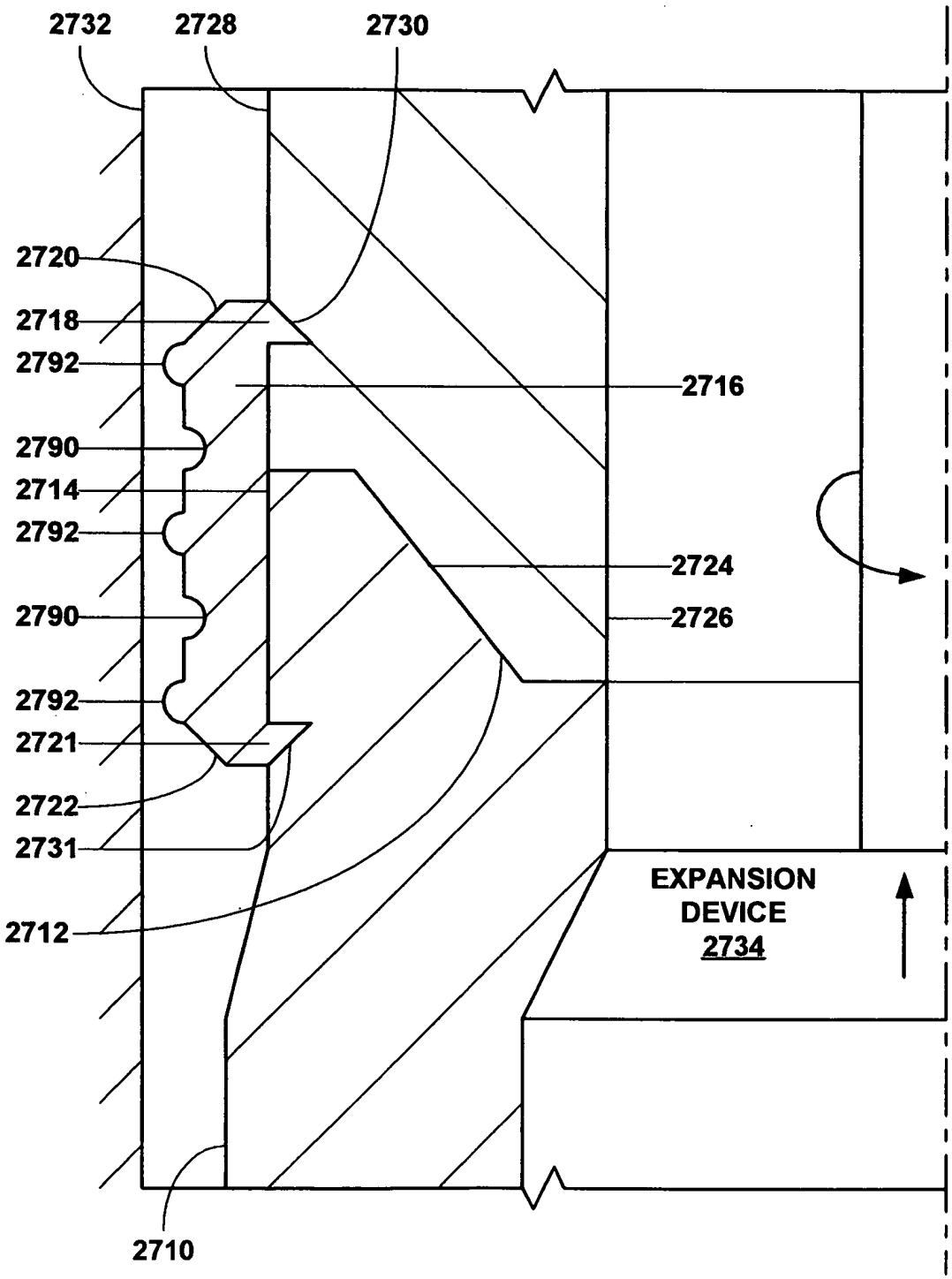
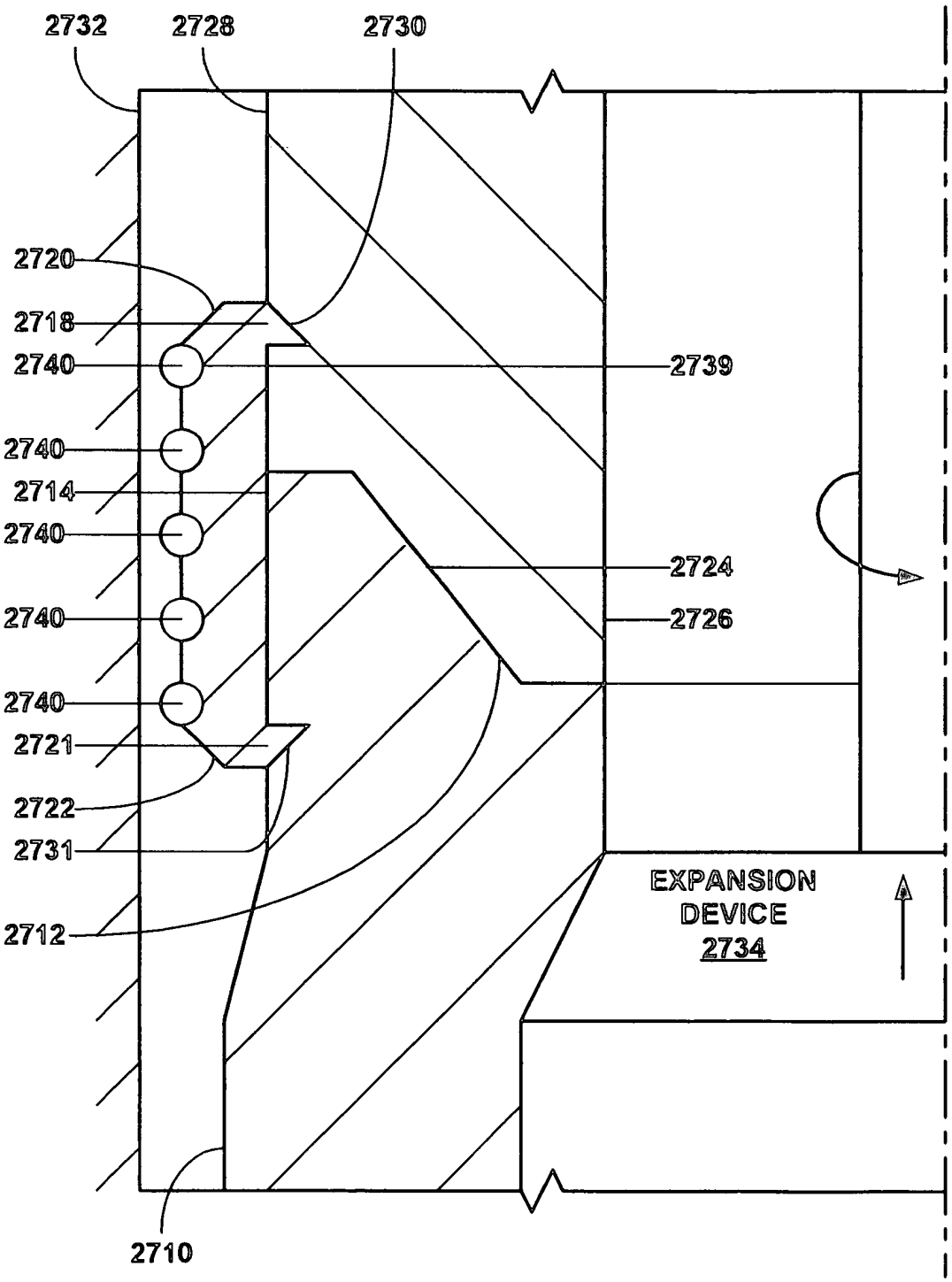

2732
2728
2730
2720
2718
2792
2716
2790
2714
2792
2724
2790
2726
2792
2721
2722
2731
2712
EXPANSION
DEVICE
2734
2710

FIG. 27


2732
2728
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2740
2739
2740
2714
2740
2724
2740
2726
2740
2721
2722
2731
2712
EXPANSION
DEVICE
2734
2710

FIG. 28

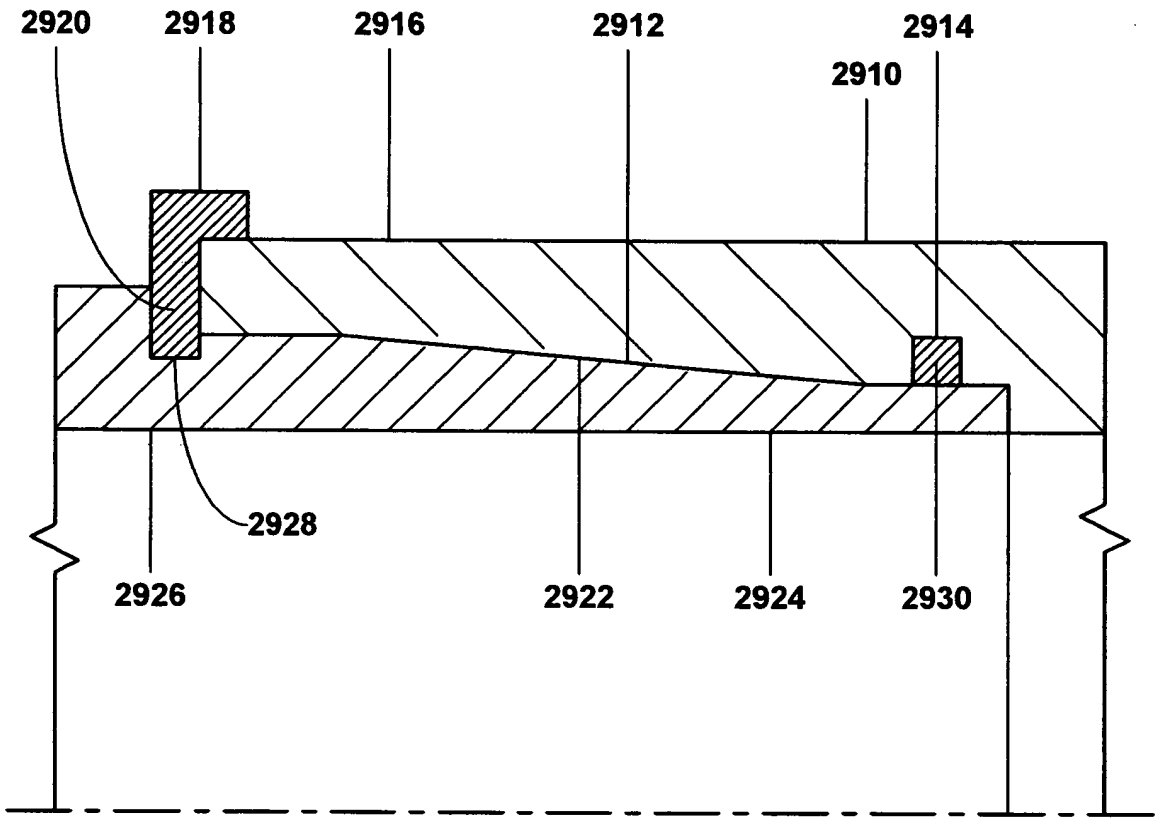


FIG. 29

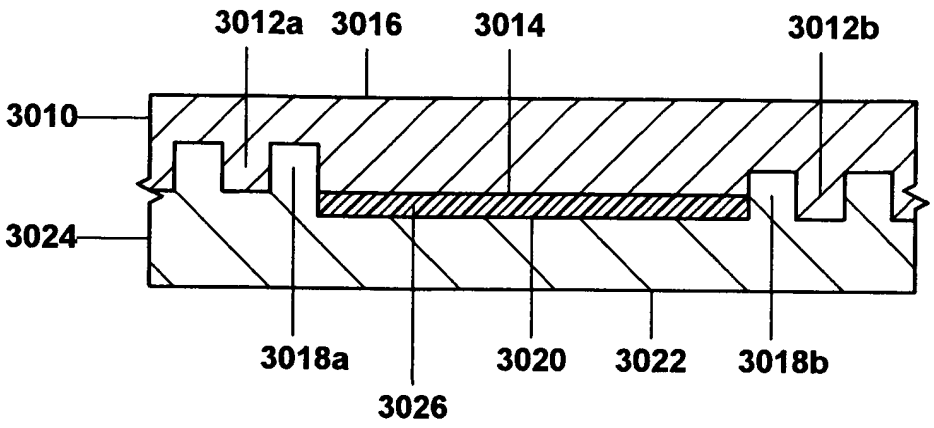


FIG. 30a

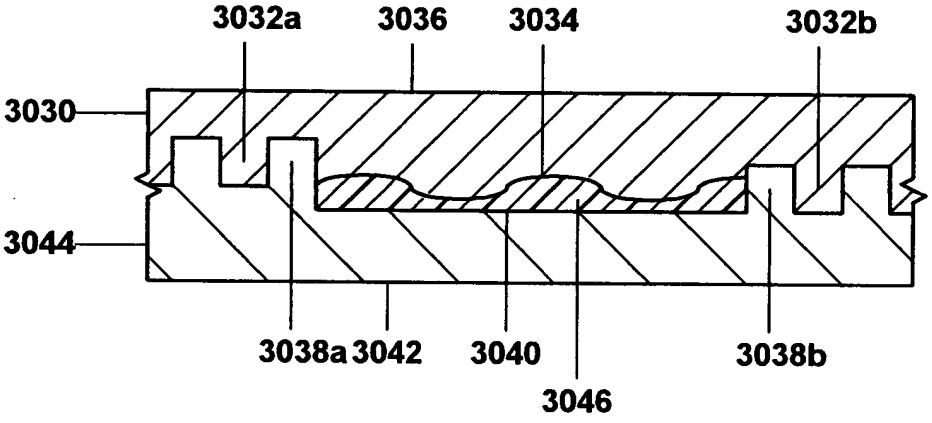


FIG. 30b

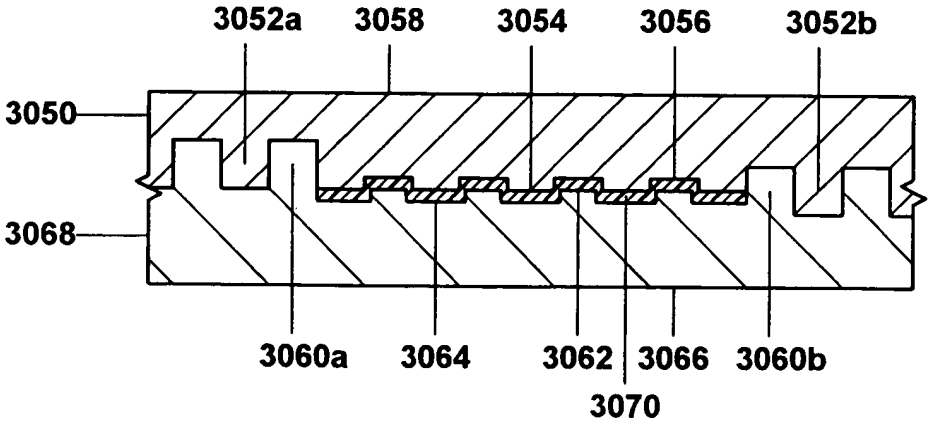


FIG. 30c

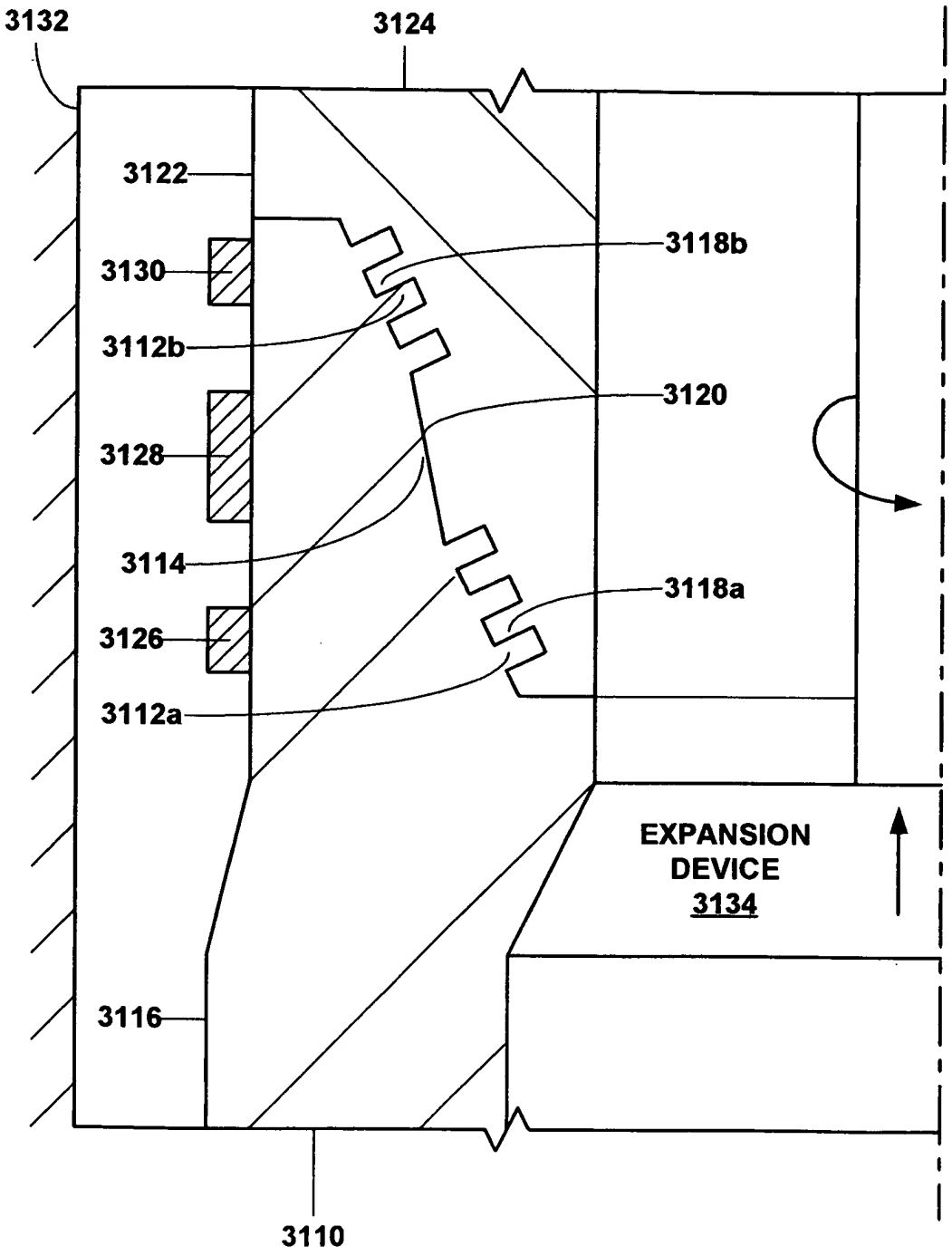

3132
3124
3122
3130
3112b
3128
3114
3126
3112a
3116
3110
3118b
3120
3118a
EXPANSION
DEVICE
3134

FIG. 31

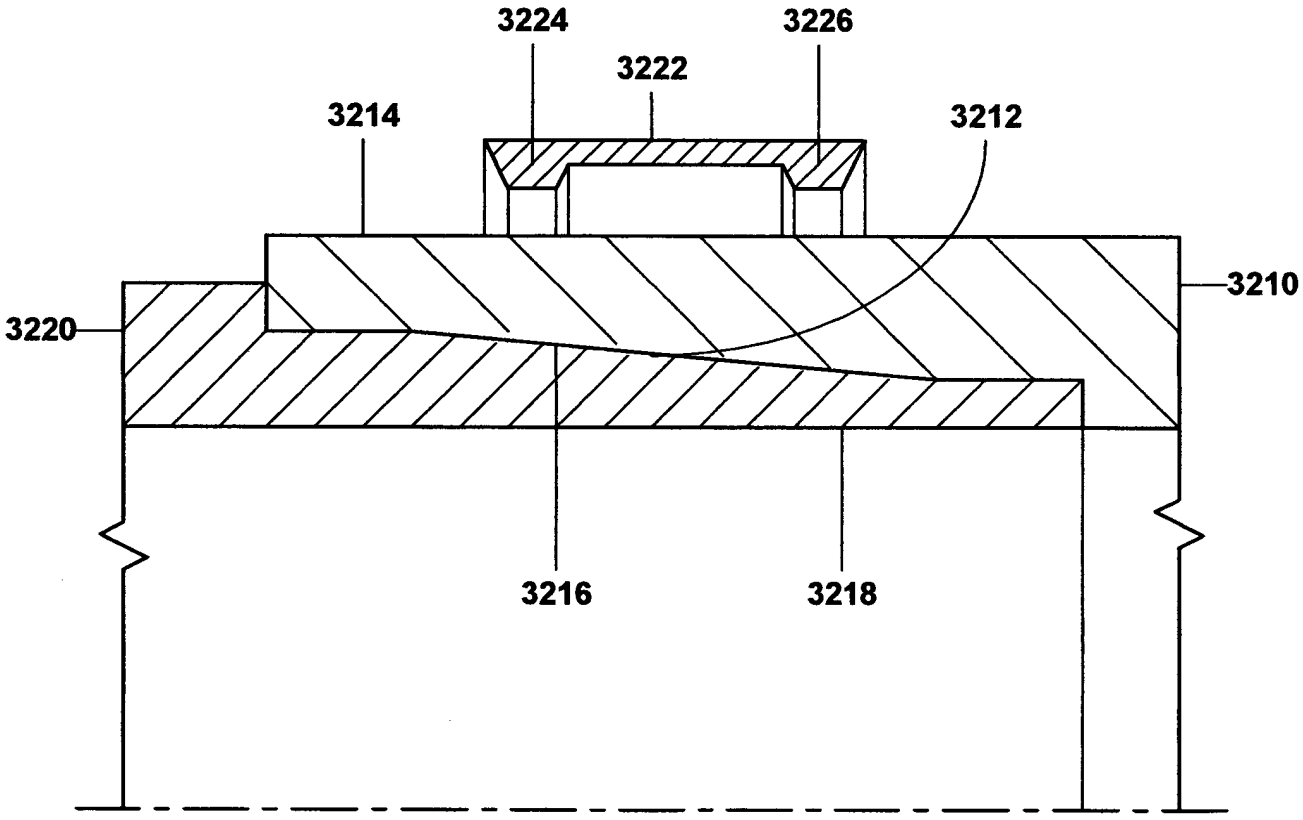


FIG. 32a

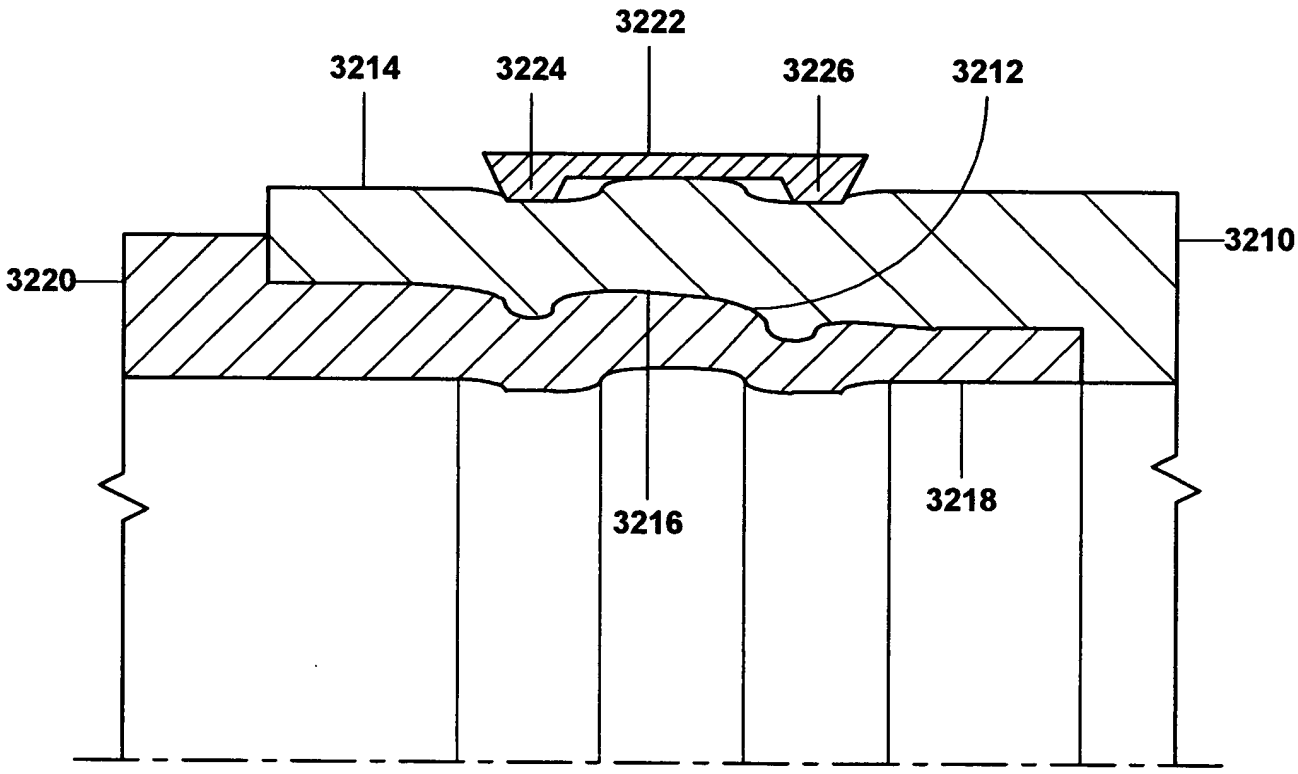
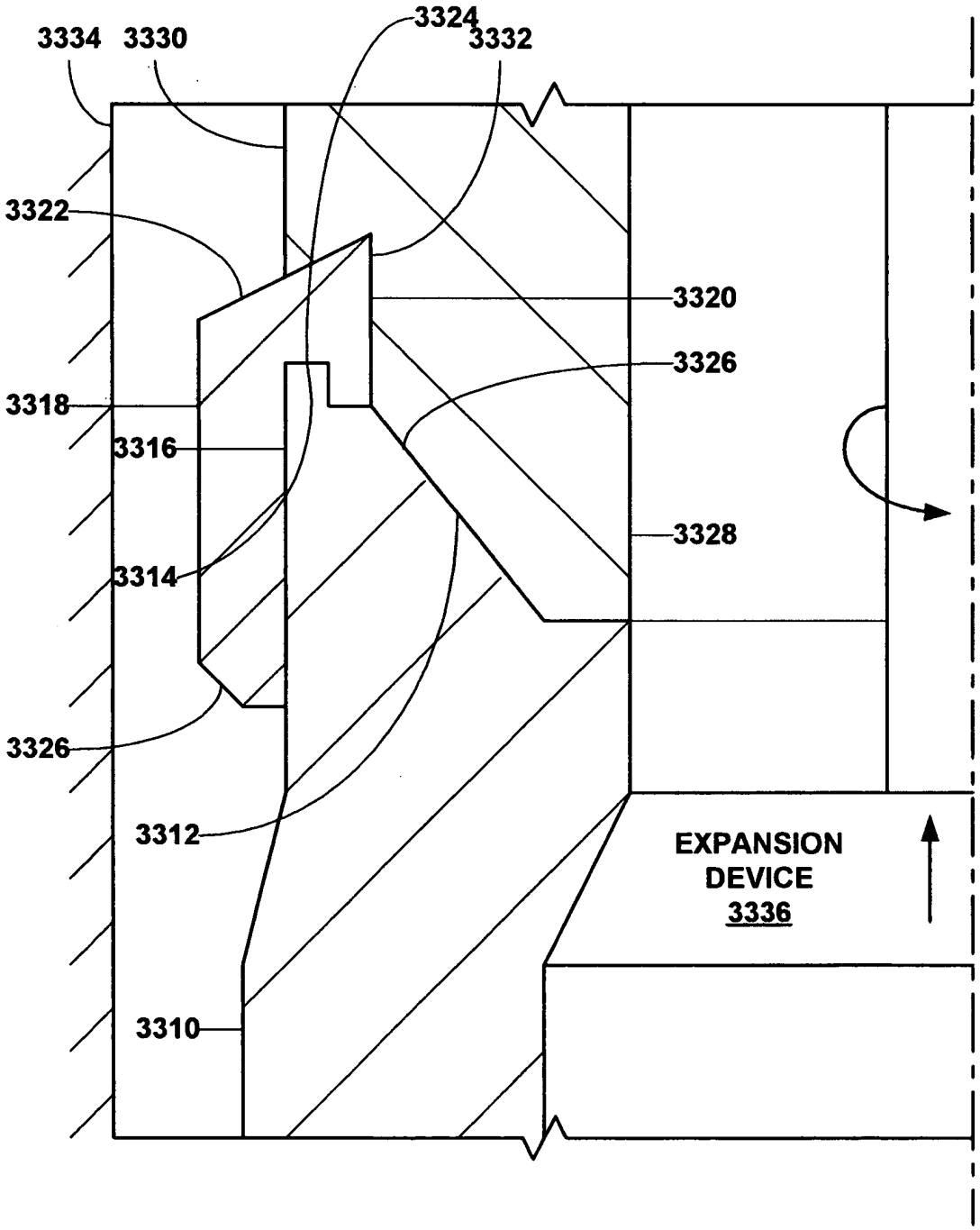


FIG. 32b


3334
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3324
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3322
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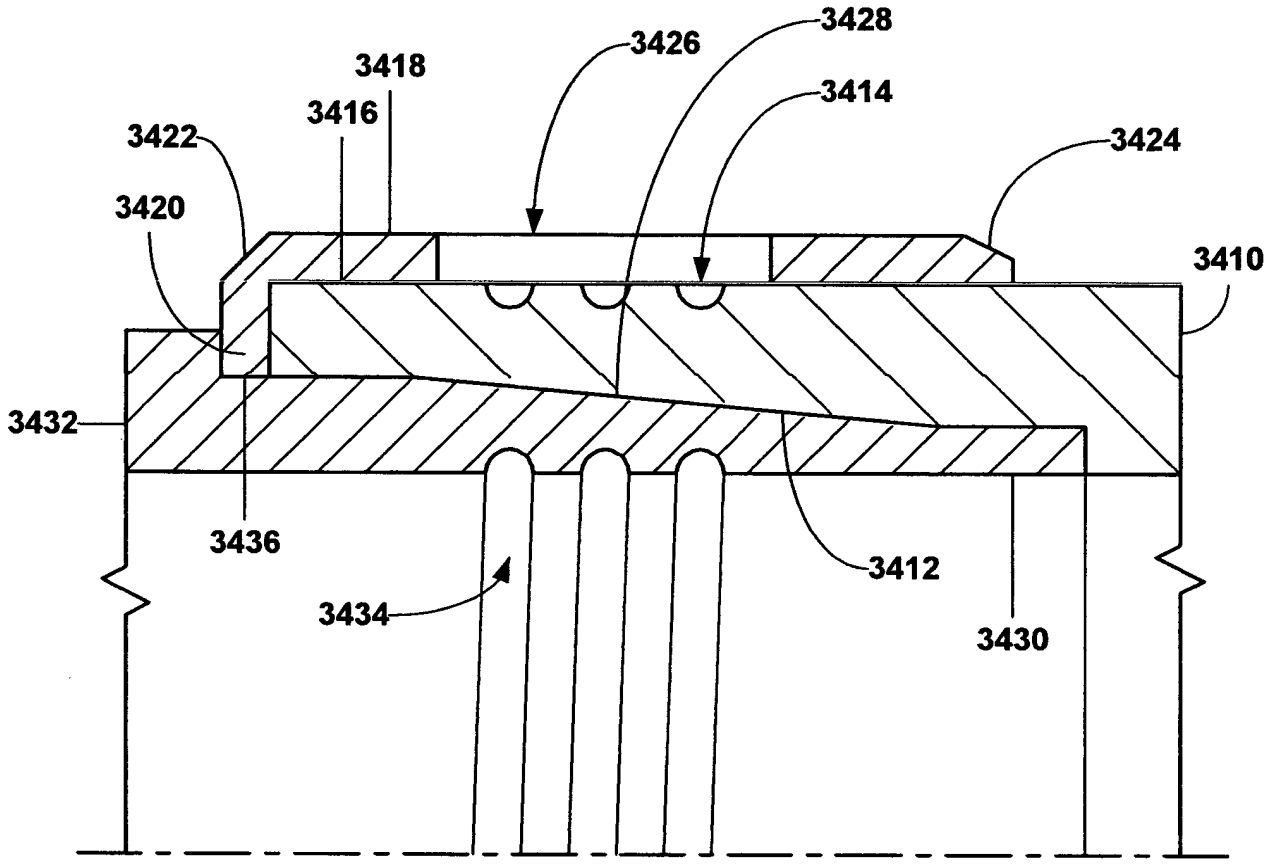
3326
3318
3316
3328
3314
3326
3312
EXPANSION
DEVICE
3336
3310

FIG. 33


3428
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3414
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3432
3436
3412
3434
3430

FIG. 34a

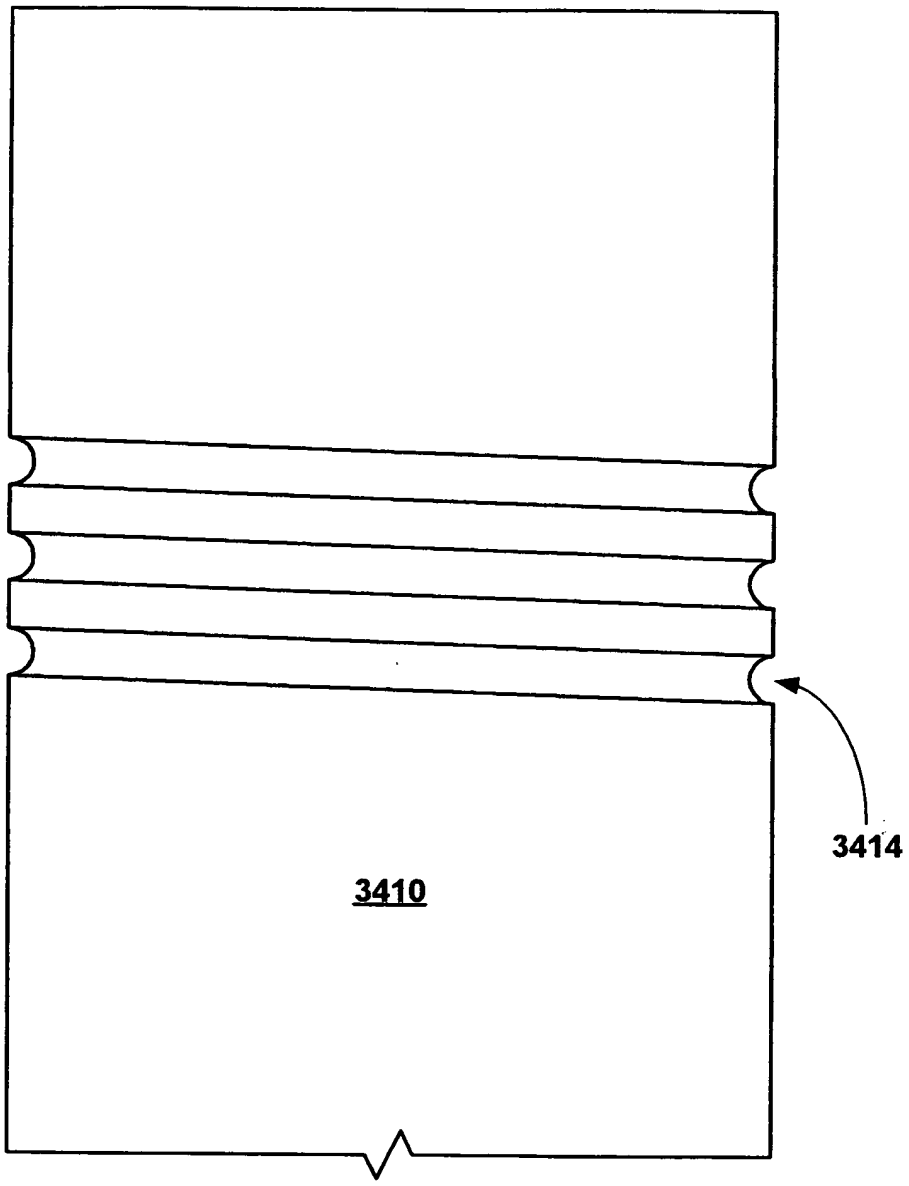


Fig. 34b

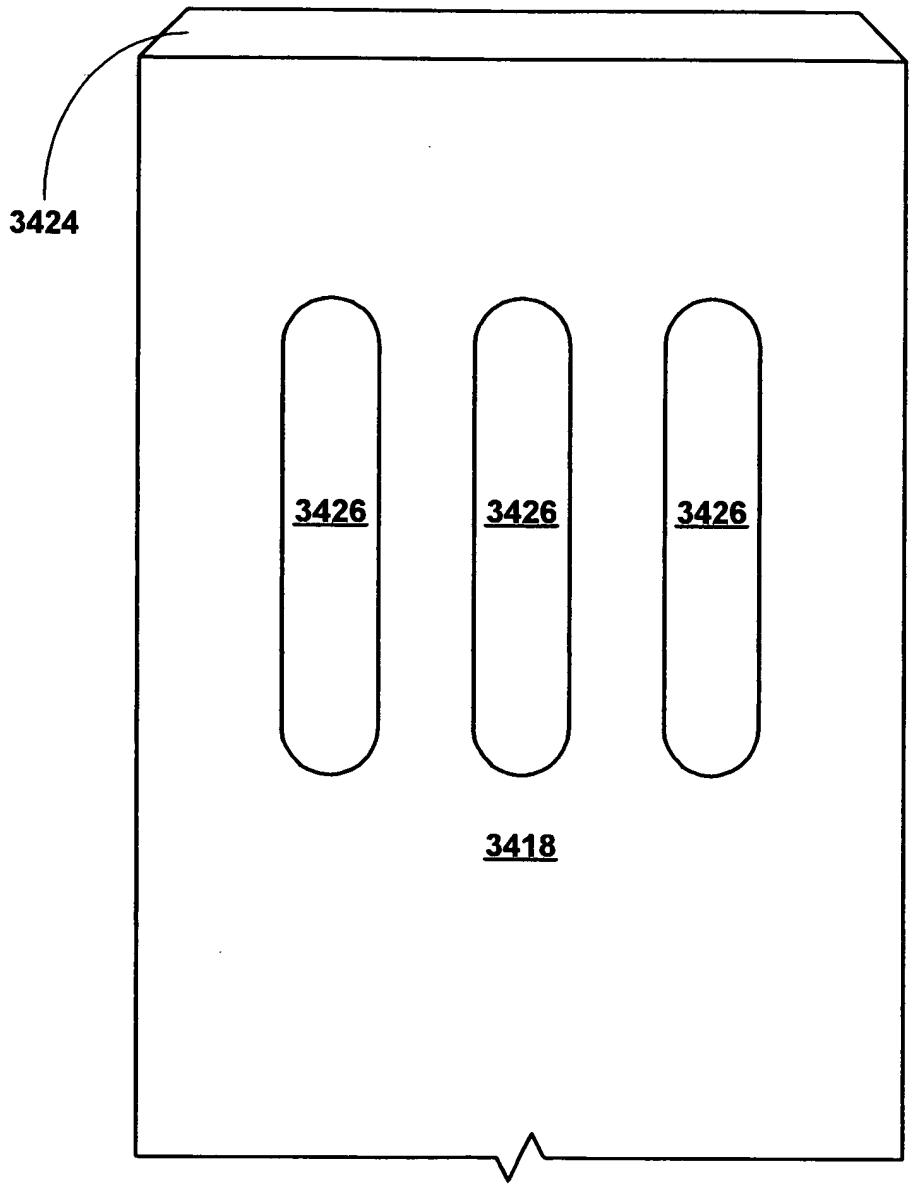


Fig. 34c

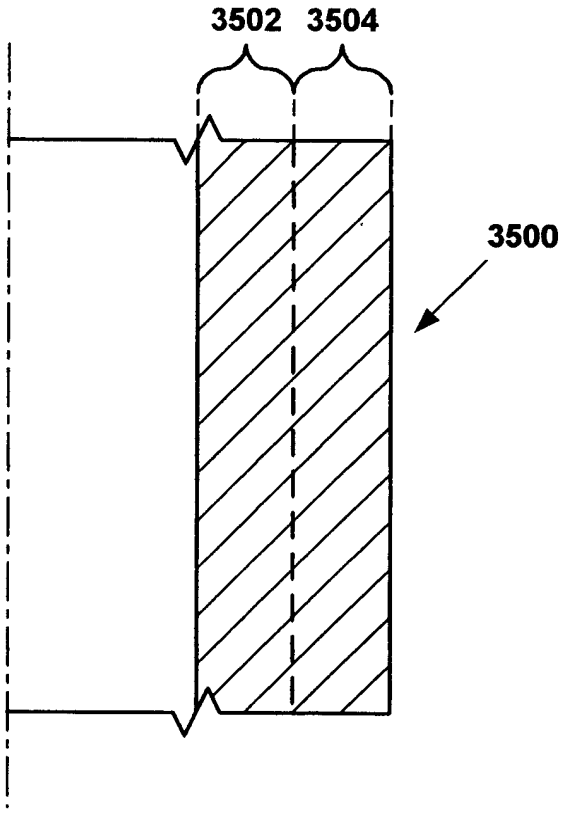


FIG. 35a

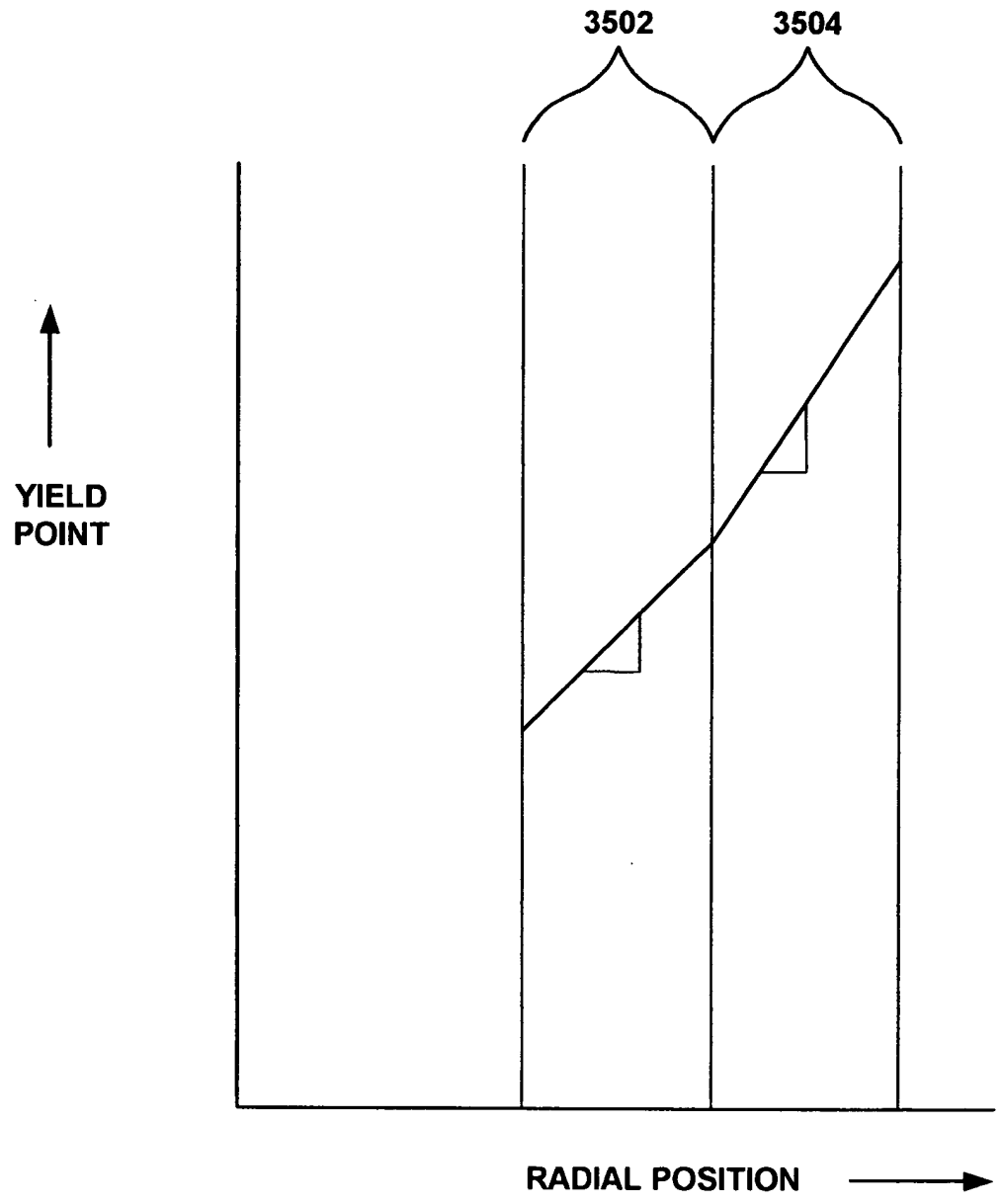


FIG. 35b

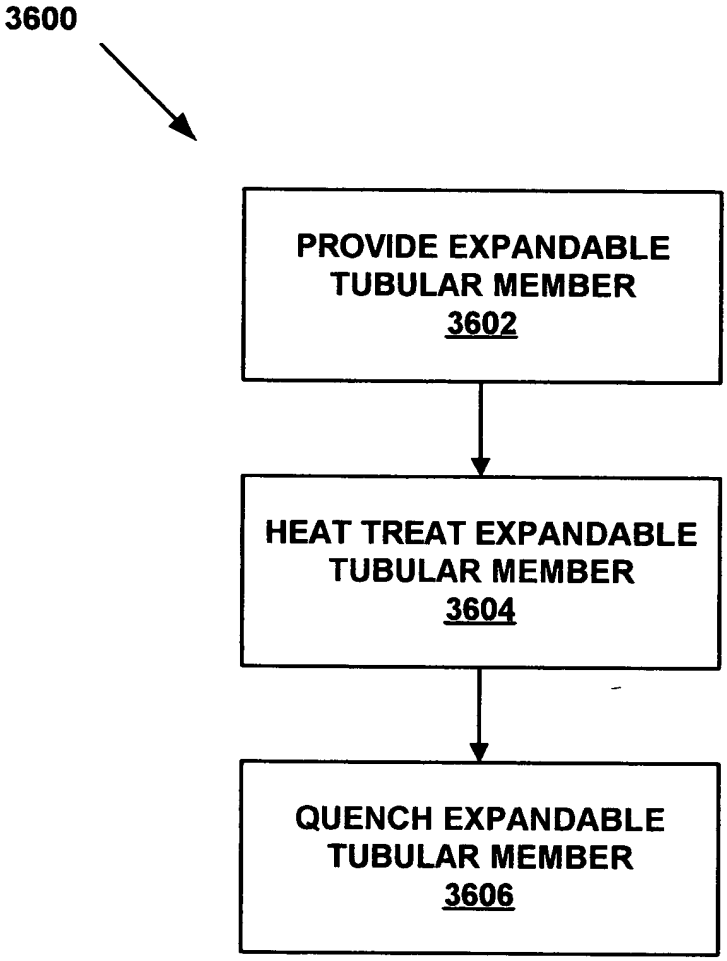

3600
PROVIDE EXPANDABLE TUBULAR MEMBER
3602
HEAT TREAT EXPANDABLE TUBULAR MEMBER
3604
QUENCH EXPANDABLE TUBULAR MEMBER
3606

FIG. 36a

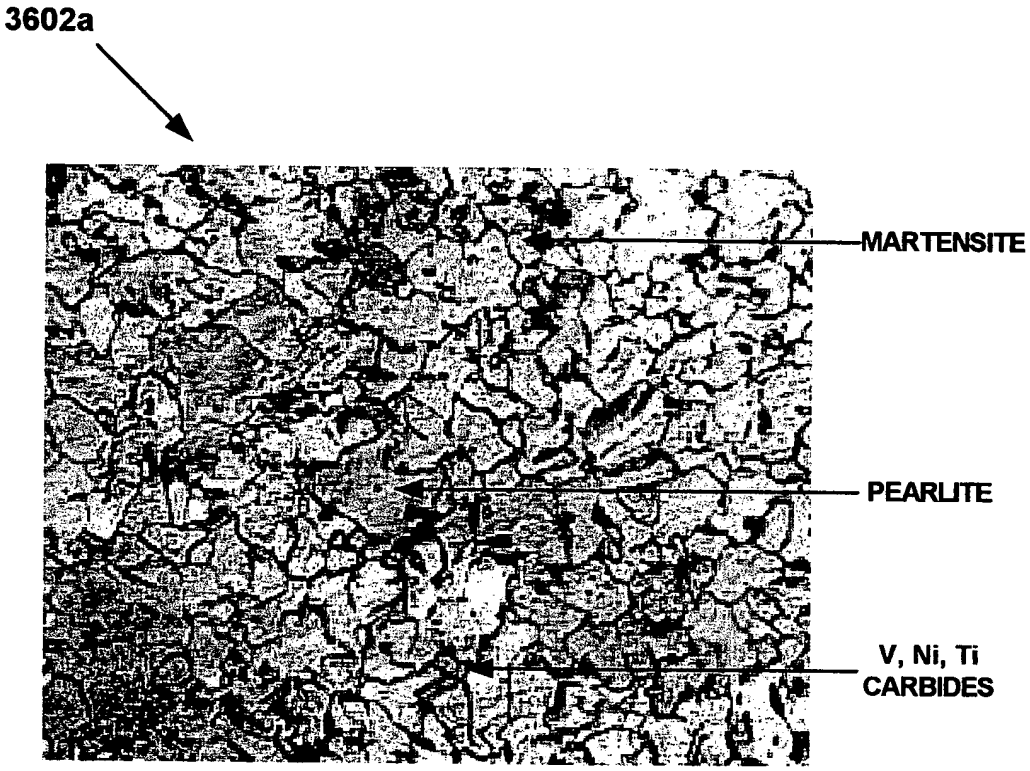


Fig. 36b

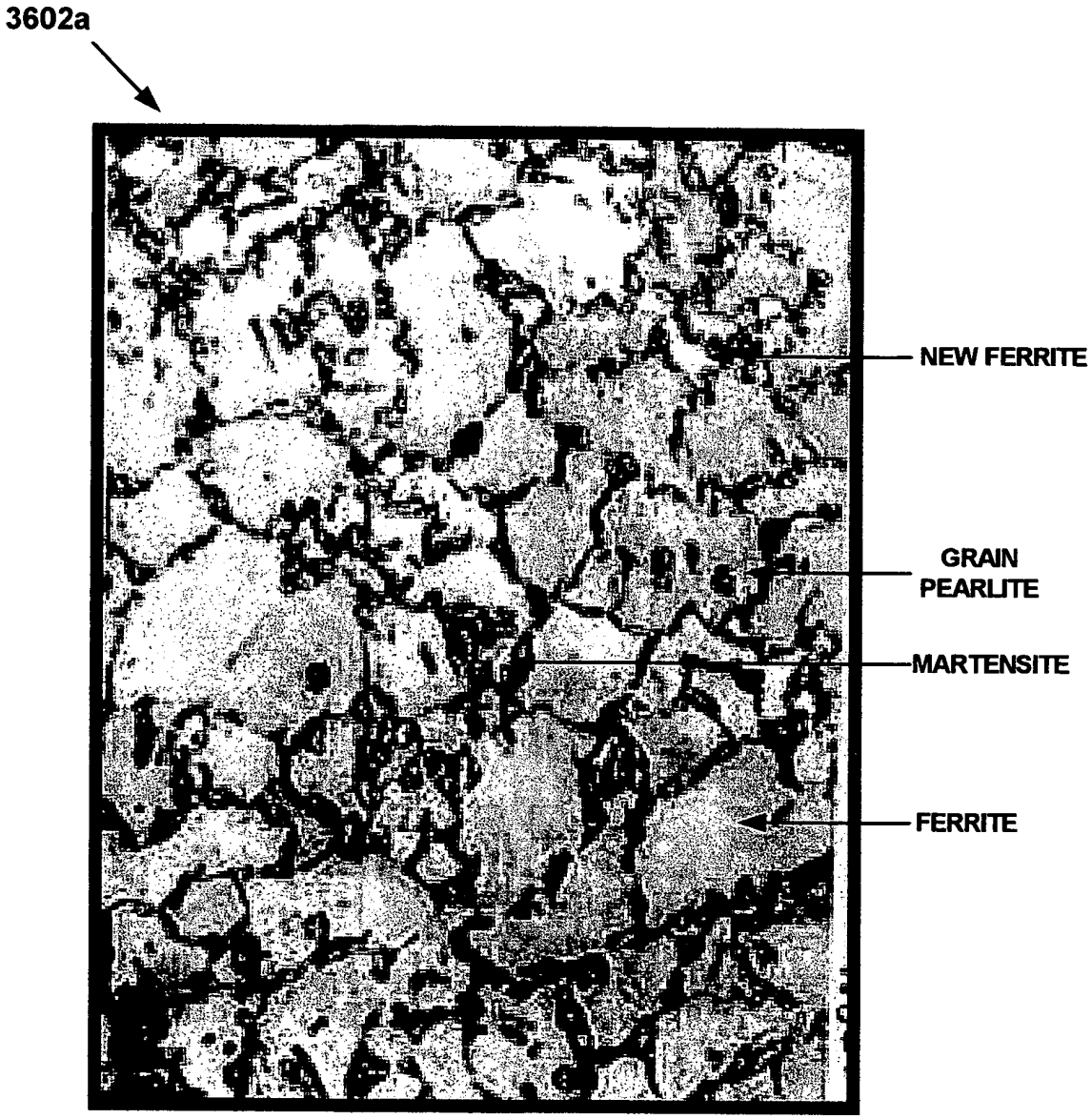


Fig. 36c

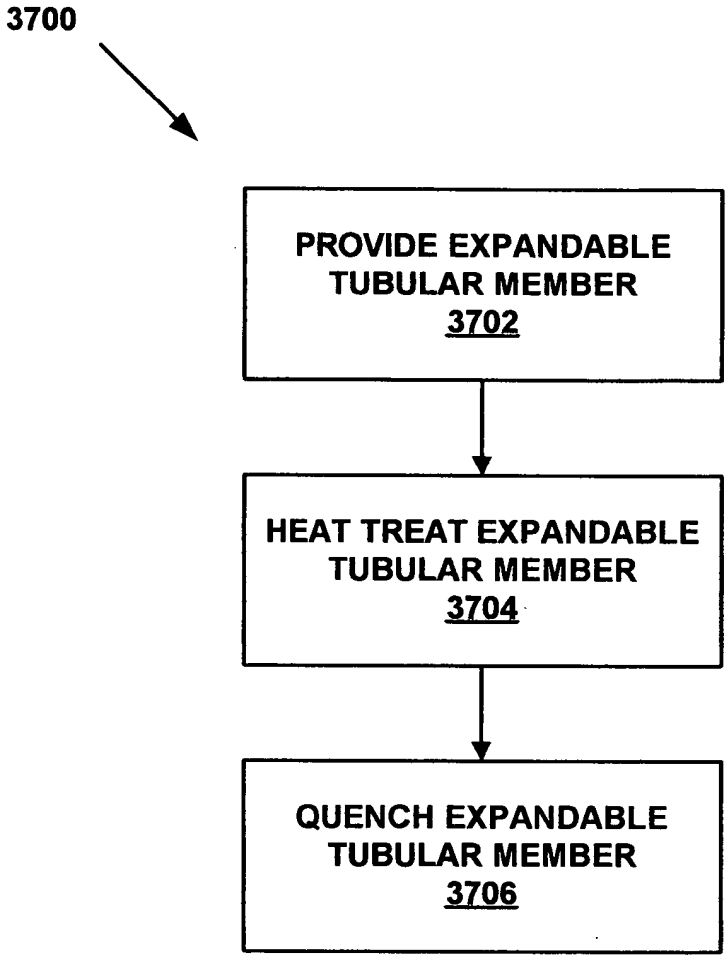

3700
PROVIDE EXPANDABLE TUBULAR MEMBER
3702
HEAT TREAT EXPANDABLE TUBULAR MEMBER
3704
QUENCH EXPANDABLE TUBULAR MEMBER
3706

FIG. 37a

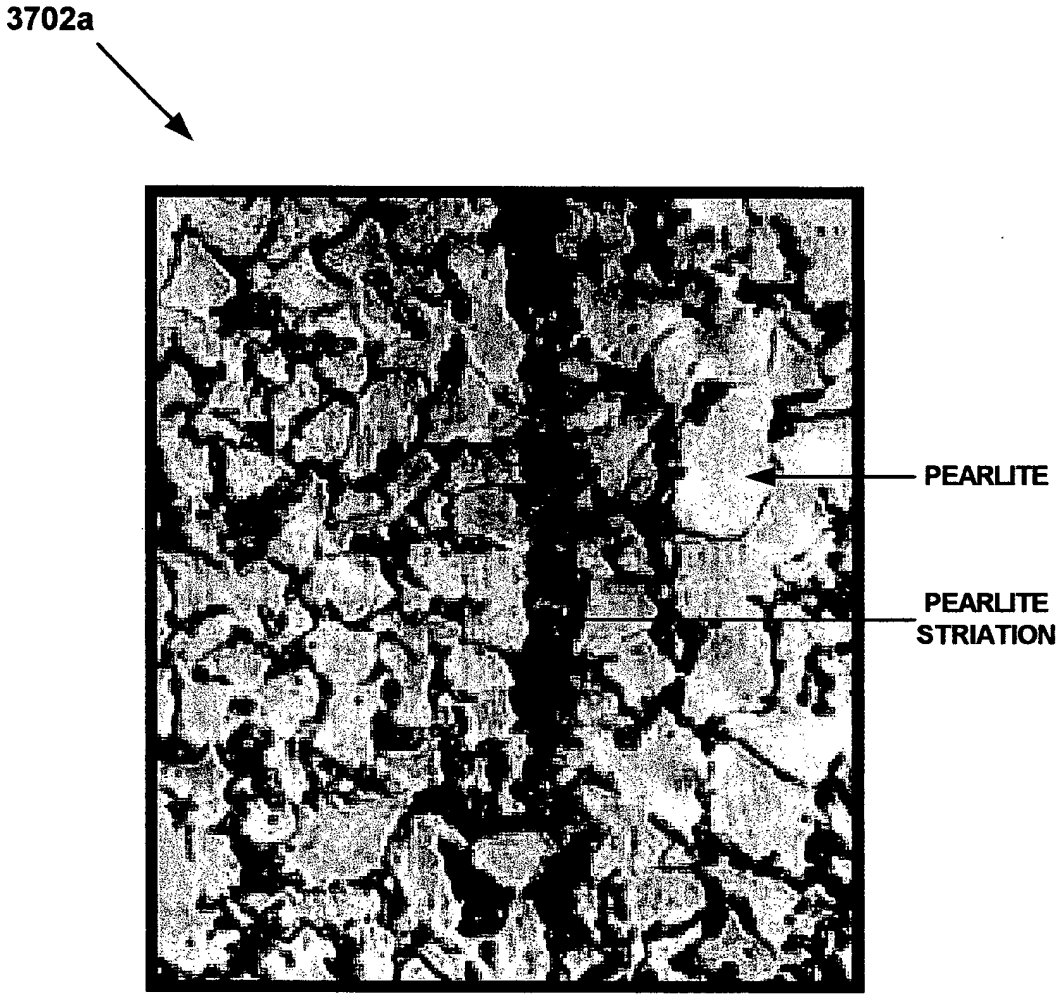


Fig. 37b

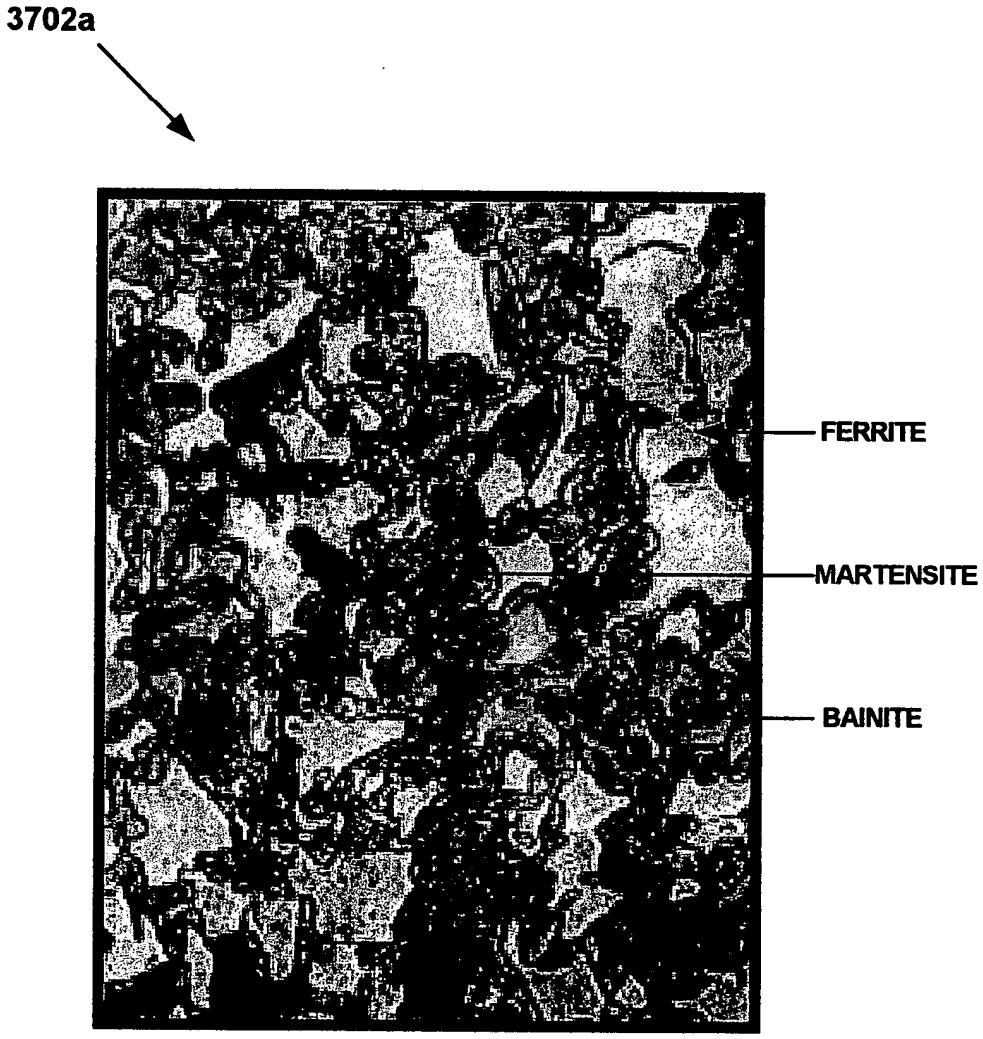


Fig. 37c

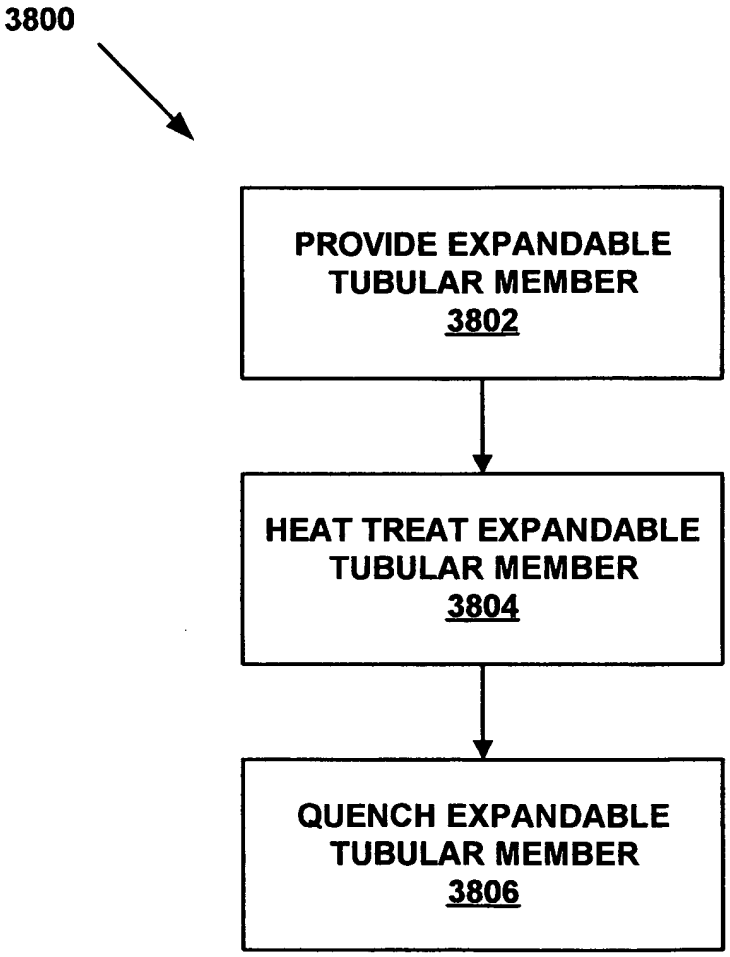

3800
PROVIDE EXPANDABLE TUBULAR MEMBER
3802
HEAT TREAT EXPANDABLE TUBULAR MEMBER
3804
QUENCH EXPANDABLE TUBULAR MEMBER
3806

FIG. 38a

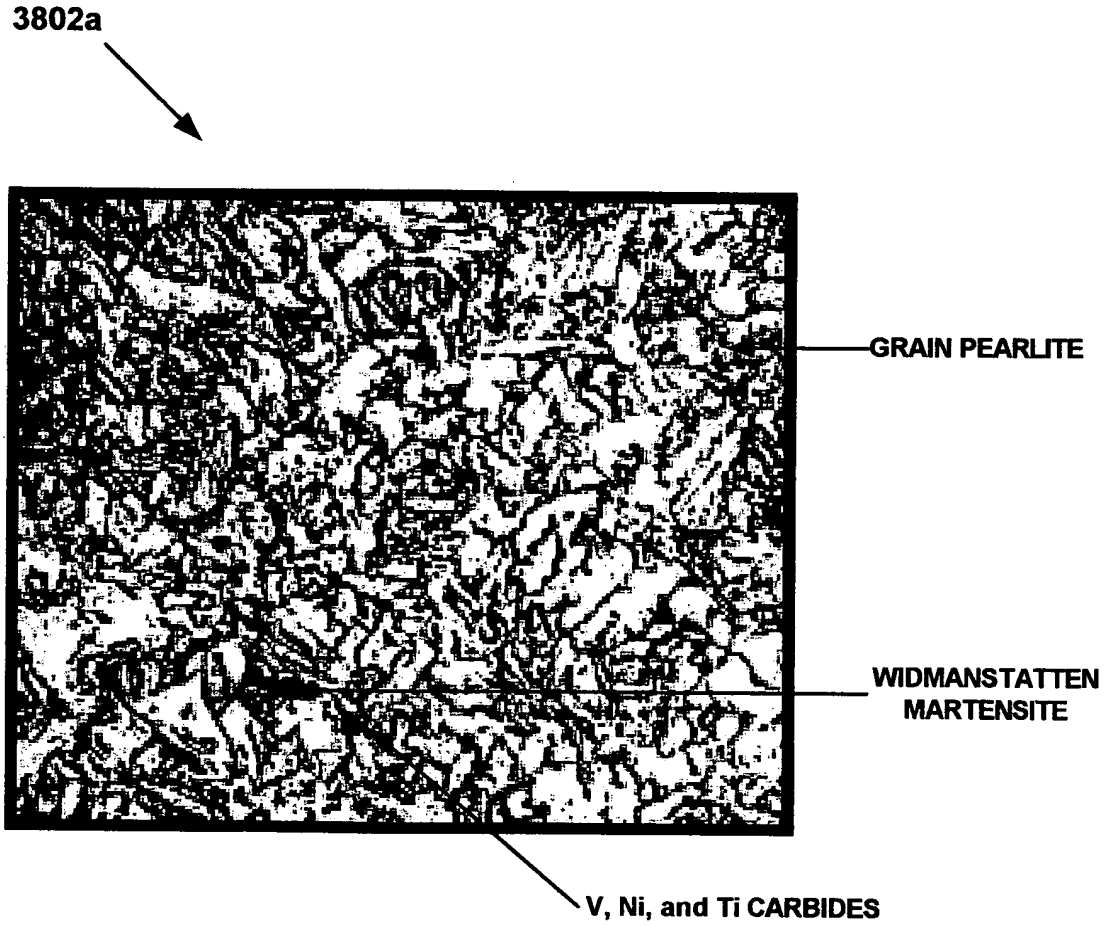

3802a
GRAIN PEARLITE
WIDMANSTATTEN
MARTENSITE
V, Ni, and Ti CARBIDES

Fig. 38b

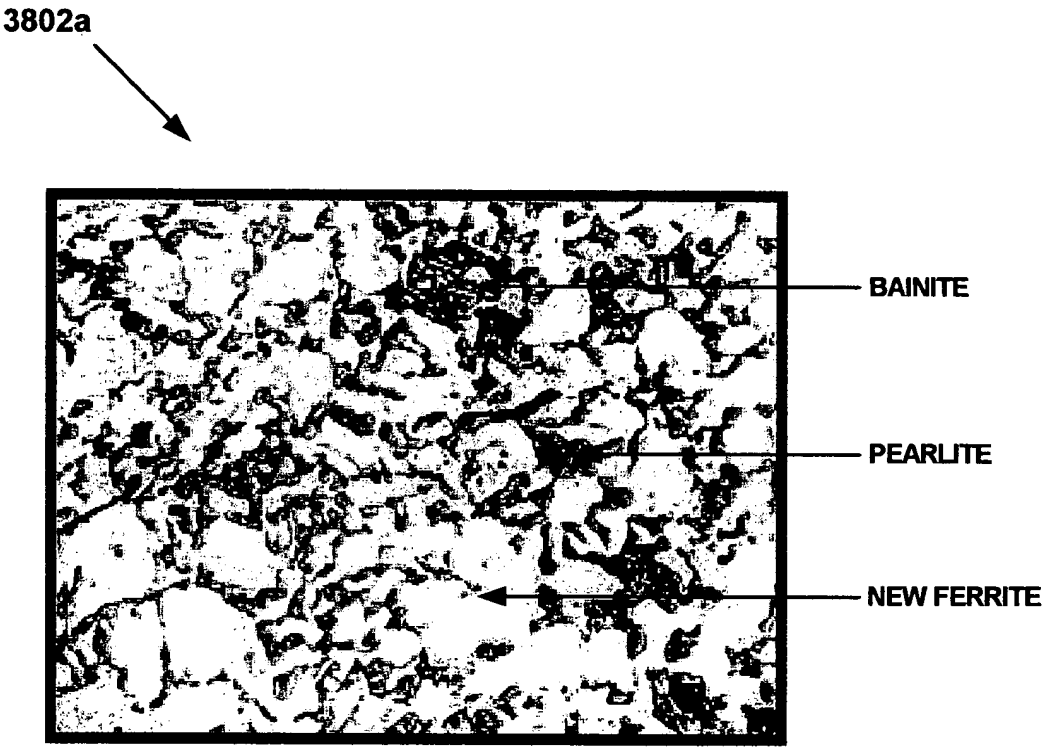


Fig. 38c

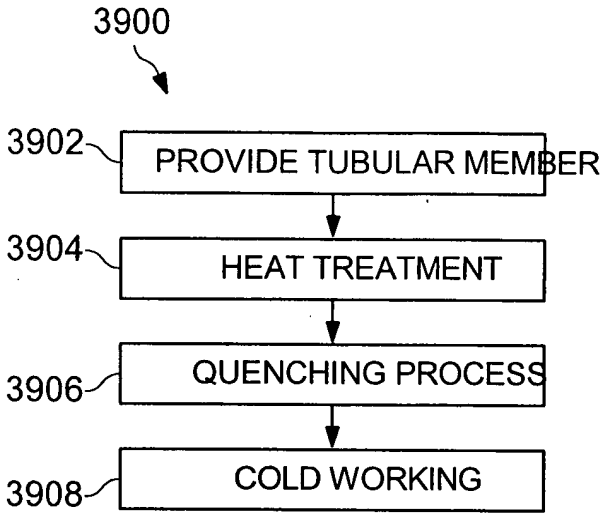


Fig. 39

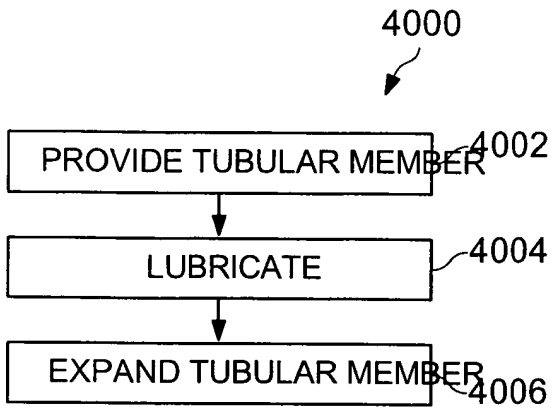


Fig. 40

4100

4102 STRESS-STRAIN PROPERTIES
- Optimum combination of the strength and elongation

4104 CHARPY V-NOTCH IMPACT VALUE
- Impact tests on notched specimens are used to predict the likelihood of brittle fracture

4106 STRESS RUPTURE (BURST, COLLAPSE)
- Higher strength is better but decreased ductility/toughness with increased susceptibility to environmental cracking

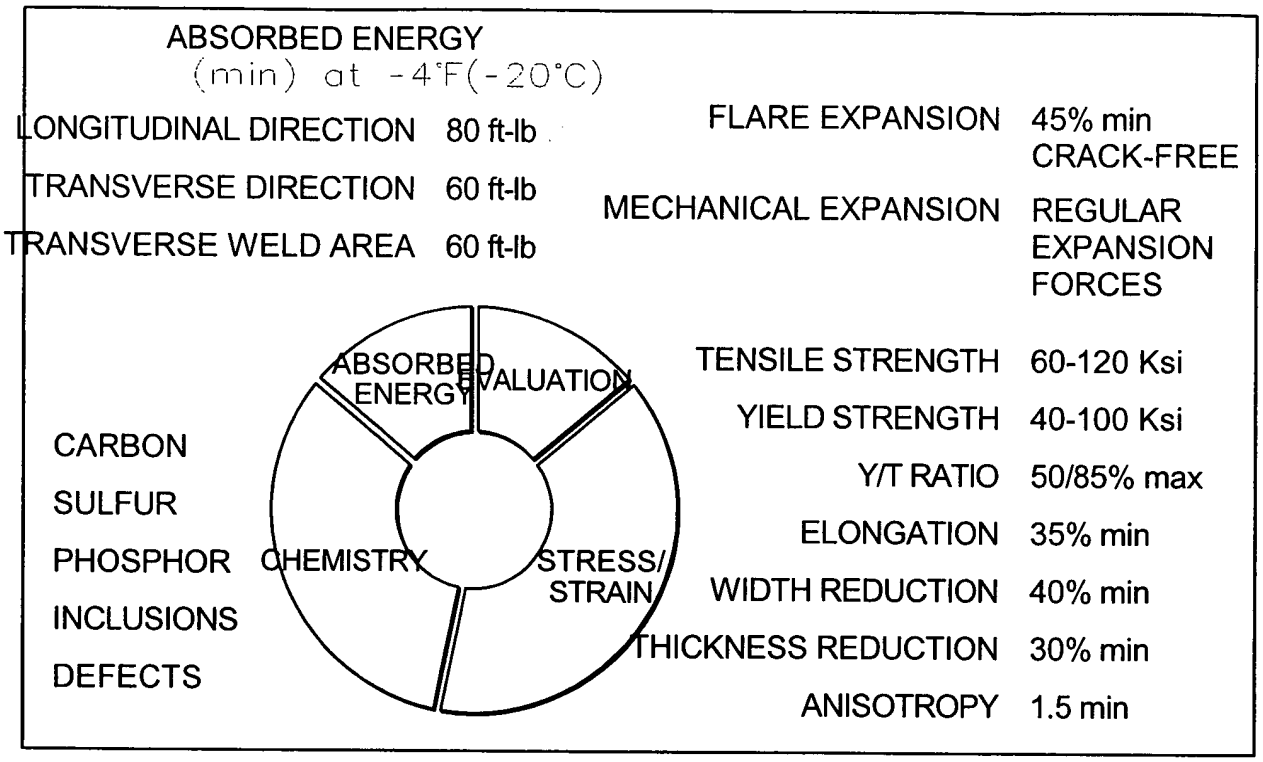
4108 STRAIN-HARDENING EXPONENT (N-VALUE)
- Material with higher strain-hardening exponent can avoid failure during tube expansion

4110 PLASTIC STRAIN RATIO (R OR LANKFORD-VALUE)
- The ratio of the strains occurring in the width and thickness directions. In case greater than 1.0 will be more resistant to thinning and better suited to tubular expansion

Fig. 41

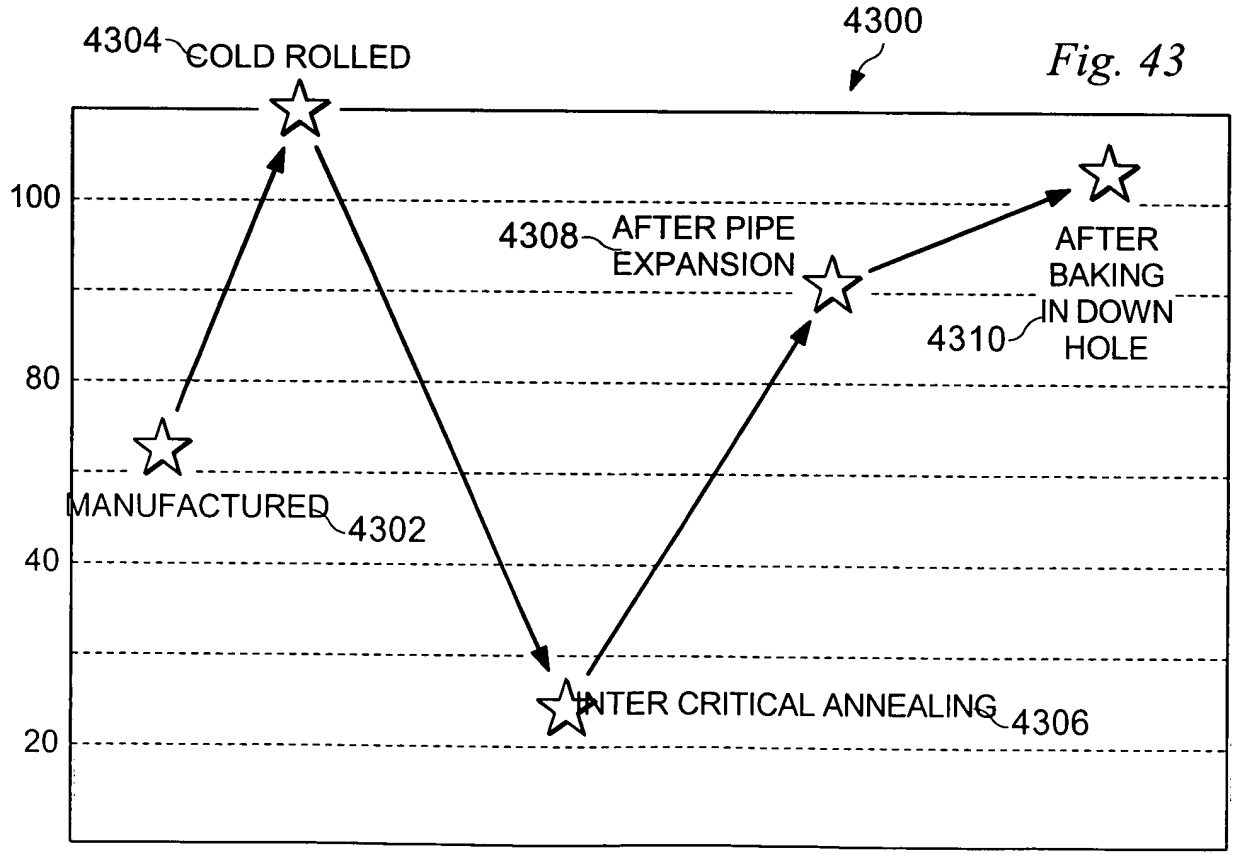
4200

Fig. 42



4300

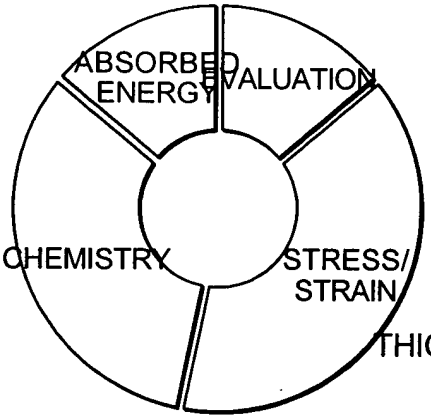
Fig. 43



4400

Fig. 44

ABSORBED ENERGY (min) at -4°F(-20°C)	
LONGITUDINAL DIRECTION	80 ft-lb
TRANSVERSE DIRECTION	60 ft-lb
TRANSVERSE WELD AREA	60 ft-lb



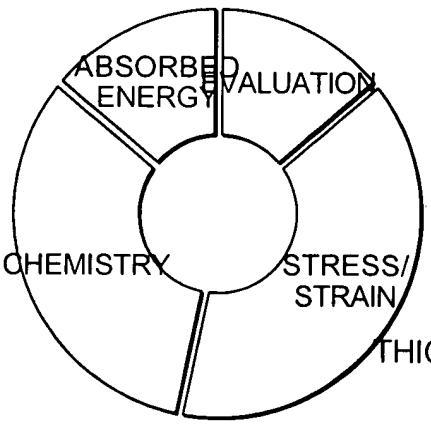
CARBON
SULFUR
PHOSPHOR
INCLUSIONS
DEFECTS

FLARE EXPANSION	45% min CRACK-FREE
MECHANICAL EXPANSION	REGULAR EXPANSION FORCES
TENSILE STRENGTH	80-100 Ksi
YIELD STRENGTH	60-90 Ksi
Y/T RATIO	85% max
ELONGATION	22% min
WIDTH REDUCTION	30% min
THICKNESS REDUCTION	35% min
ANISOTROPY	0.8 min

4500

Fig. 45

ABSORBED ENERGY (min) at -4°F(-20°C)	
LONGITUDINAL DIRECTION	80 ft-lb
TRANSVERSE DIRECTION	60 ft-lb
TRANSVERSE WELD AREA	60 ft-lb



CARBON
SULFUR
PHOSPHOR
INCLUSIONS
DEFECTS

FLARE EXPANSION	75% min CRACK-FREE
MECHANICAL EXPANSION	REGULAR EXPANSION FORCES
TENSILE STRENGTH	60-120 Ksi
YIELD STRENGTH	40-100 Ksi
Y/T RATIO	50/85% max
ELONGATION	35% min
WIDTH REDUCTION	40% min
THICKNESS REDUCTION	30% min
ANISOTROPY	1.5 min

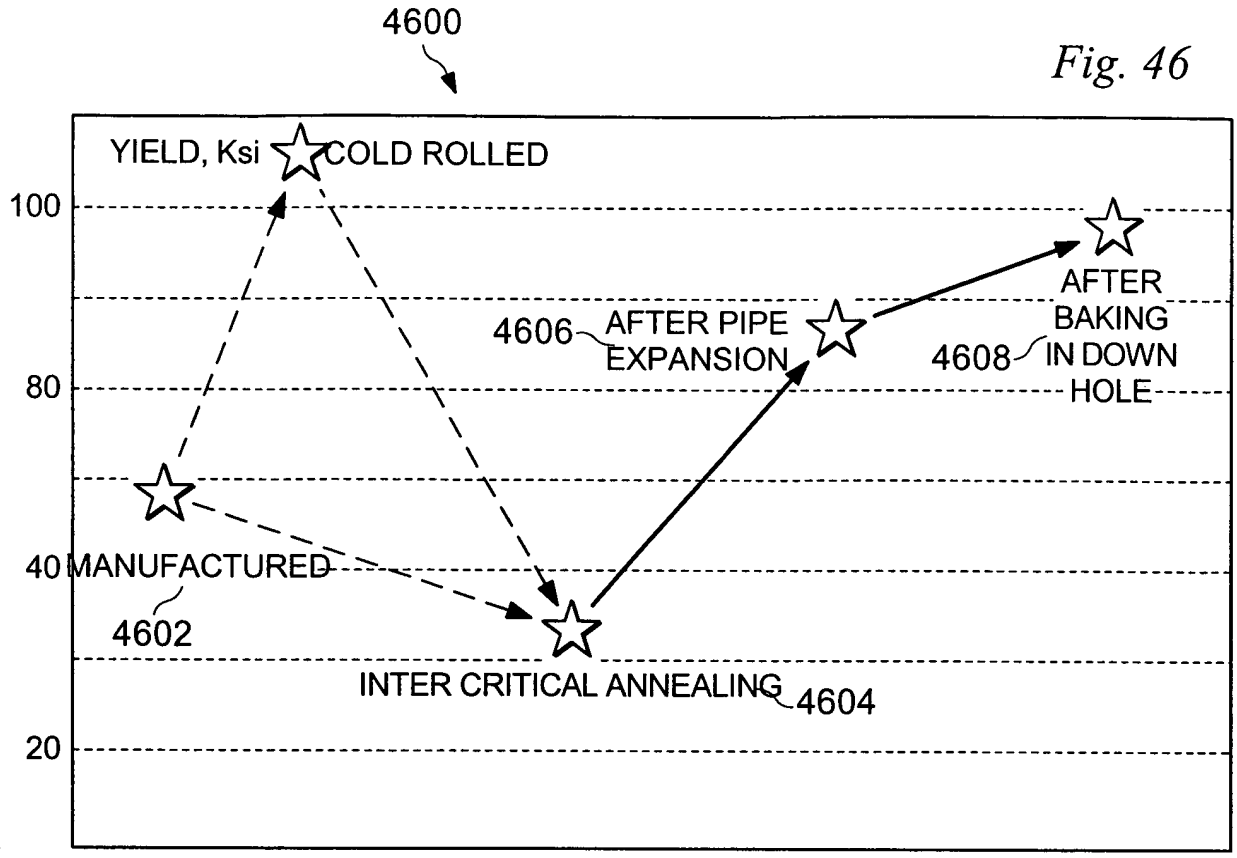


Fig. 46

4700

Fig. 47

- NEW METALLURGY
- WARM-REDUCING NEW MANUFACTURING PROCESS
- HIGH STRENGTH AND EXCELLENT FORMABILITY
- 20% HIGHER ELONGATION
- HIGH R-VALUE (=STRAIN IN DIFFERENT DIRECTIONS)

	YIELD, Ksi	TENSILE Ksi	ELONGATION %
"HISTORY" PIPE	76.8	82.8	32
ERW PIPE	64.8	85.0	18

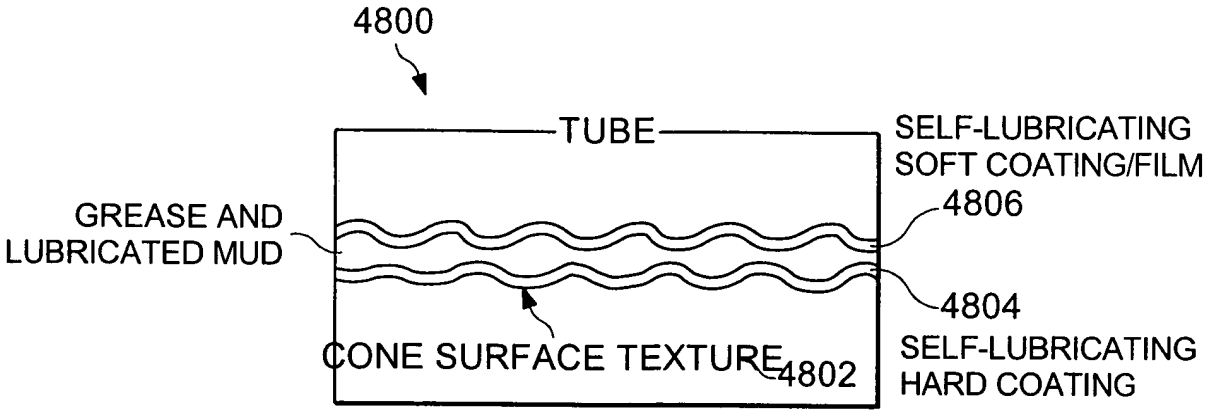

4800
TUBE
SELF-LUBRICATING
SOFT COATING/FILM
4806
GREASE AND
LUBRICATED MUD
4804
CONE SURFACE TEXTURE
4802
SELF-LUBRICATING
HARD COATING

Fig. 48

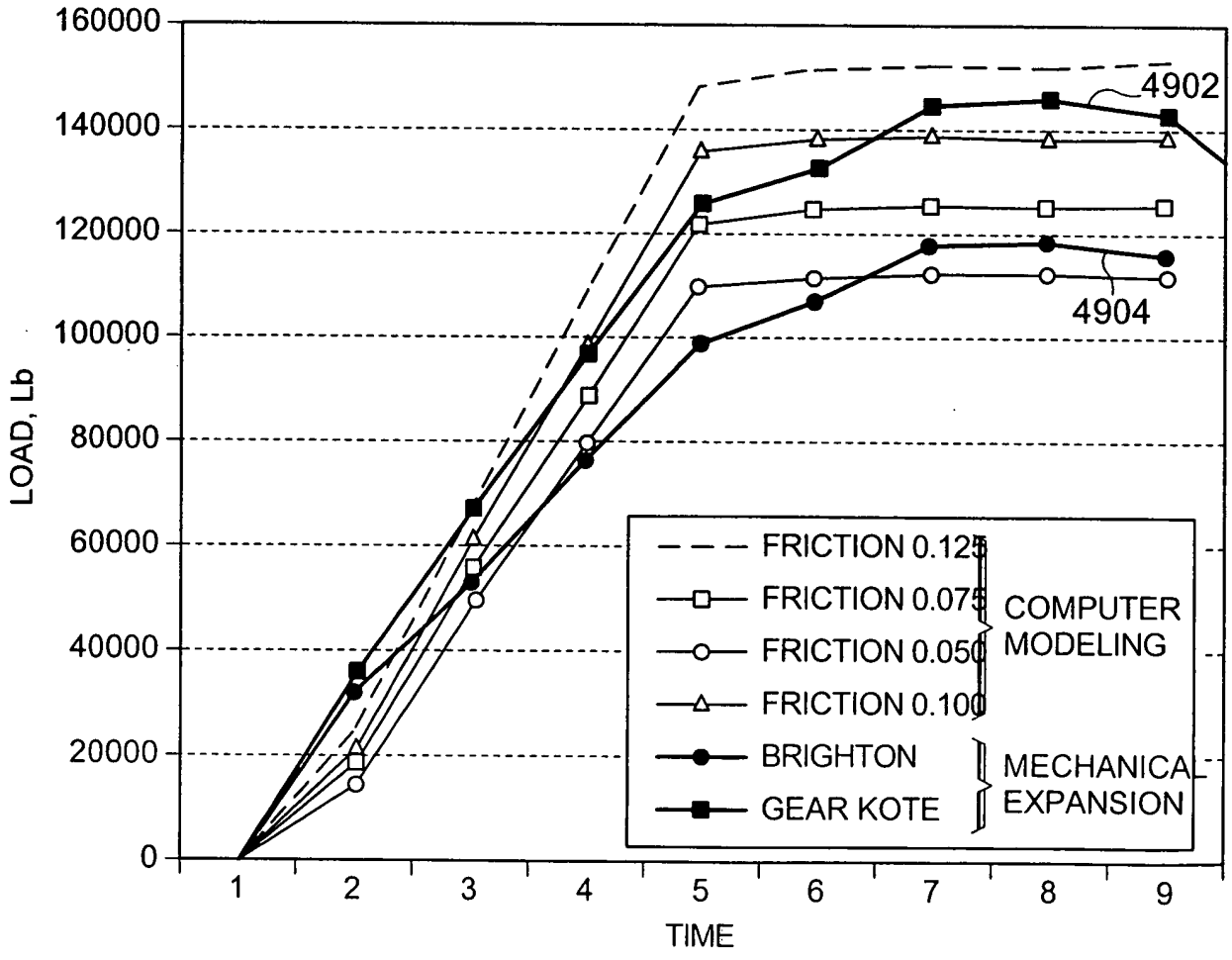
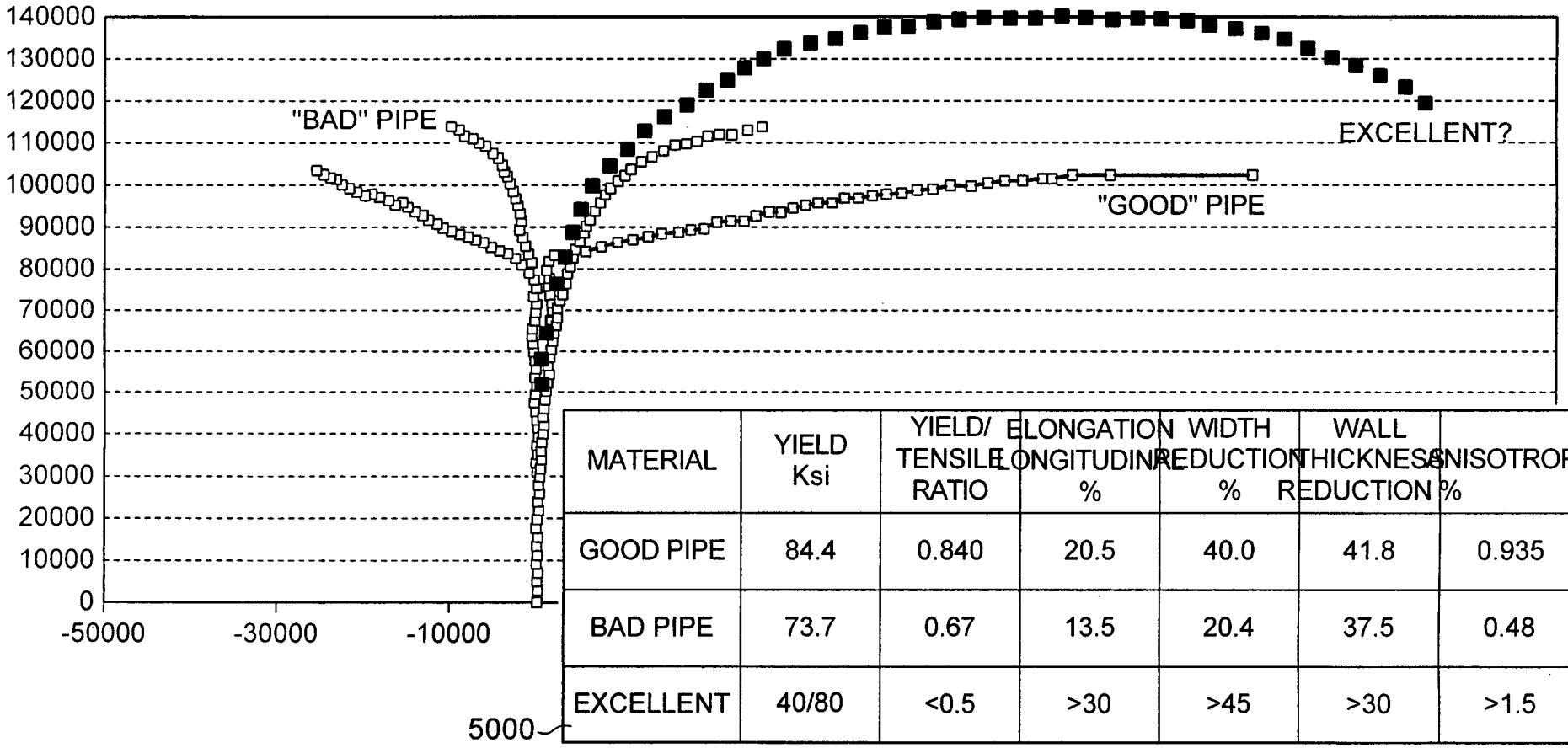

160000
140000
120000
100000
80000
60000
40000
20000
0
LOAD, Lb
1
2
3
4
5
6
7
8
9
TIME
4902
4904
FRICTION 0.125
FRICTION 0.075
FRICTION 0.050
FRICTION 0.100
BRIGHTON
GEAR KOTE
COMPUTER
MODELING
MECHANICAL
EXPANSION

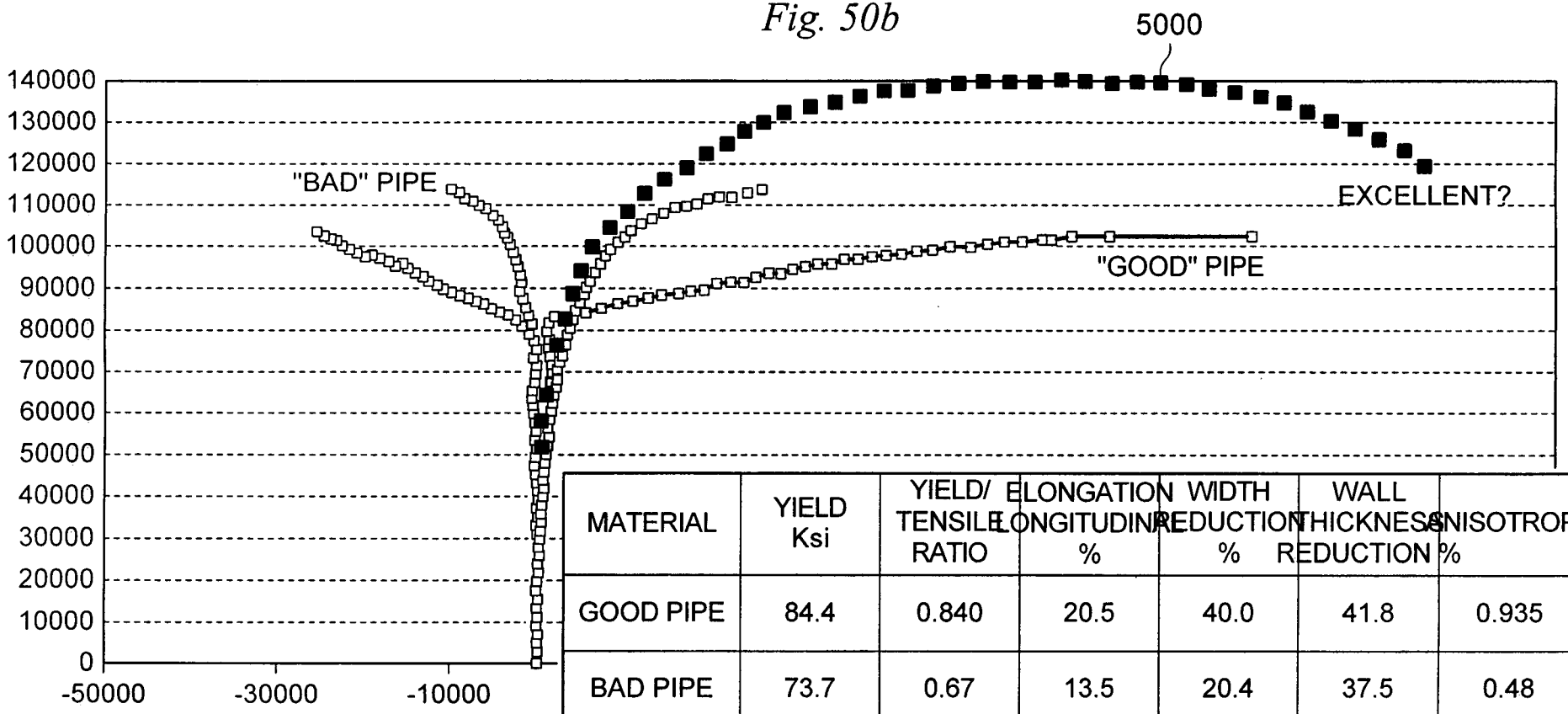
Fig. 49

Fig. 50a



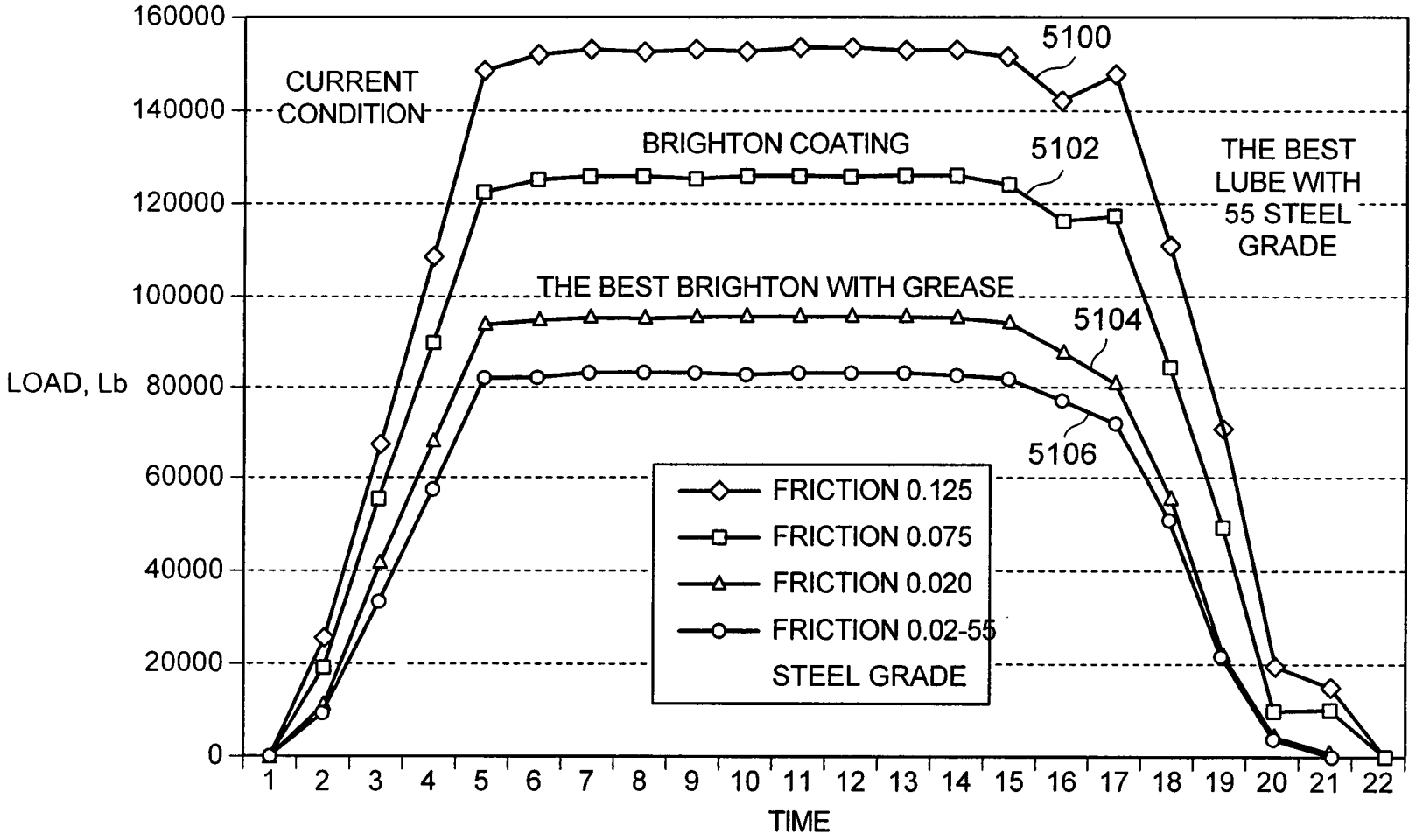
MATERIAL	YIELD Ksi	YIELD/ TENSILE RATIO	ELONGATION LONGITUDINAL %	WIDTH REDUCTION %	WALL THICKNESS REDUCTION %	ANISOTROPY
GOOD PIPE	84.4	0.840	20.5	40.0	41.8	0.935
BAD PIPE	73.7	0.67	13.5	20.4	37.5	0.48
EXCELLENT	40/80	<0.5	>30	>45	>30	>1.5

Fig. 50b



MATERIAL	YIELD Ksi	YIELD/ TENSILE RATIO	ELONGATION LONGITUDINAL %	WIDTH REDUCTION %	WALL THICKNESS REDUCTION %	ANISOTROPY
GOOD PIPE	84.4	0.840	20.5	40.0	41.8	0.935
BAD PIPE	73.7	0.67	13.5	20.4	37.5	0.48
EXCELLENT	40/80	<0.5	>30	>45	>30	>1.5

Fig. 51


160000
140000
120000
100000
80000
60000
40000
20000
0
LOAD, Lb
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
TIME
CURRENT CONDITION
BRIGHTON COATING
THE BEST BRIGHTON WITH GREASE
THE BEST LUBE WITH 55 STEEL GRADE
5100
5102
5104
5106
FRICTION 0.125
FRICTION 0.075
FRICTION 0.020
FRICTION 0.02-55 STEEL GRADE

	FRICTION	EXPANSION FORCE	WALL THICKNESS	D/t AFTER	COLLAPSE Ksi
5200 CURRENT 6" x .305 BSFL LUBE	0.125	145,900	0.305	24.8	2,379
5202 BRIGHTON LUBE APPLICATION	0.075	143,000	0.350	21.6	3,243
5204 BEST BRIGHTON WITH GREASE	0.020	149,900	0.450	16.8	5,837
5206 BEST LUBE WITH 55 Ksi STEEL	0.020	125,800	0.500	15.1	5,359
5208 BEST LUBE AND STEEL WITH 55 Ksi YIELD BEFORE AND 100 Ksi AFTER PIPE EXPANSION	0.020	126,800	0.500	15.1	8,443

Fig. 52

	SAMPLE	C	Mn	P	S	Si	Cu	Ni	Cr	V	Mo	Nb	Ti
5302	JFE-A*	.065	1.44	.010	.002	.24	.01	.01	.02	.04	.01	.03	.01
5304	JFE-B*	.180	1.28	.017	.004	.29	.01	.01	.03	.03	.03	.01	.01
5306	X52x0.37	.080	0.82	.006	.003	.30	.16	.05	0.5	.06	.01	.03	.01
5308	X52x0.52	.030	1.48	.014	.002	.16	.02	.01	.02	.06	.01	.03	.01

Fig. 53

5400

	5402 YIELD Ksi	5404 YIELD RATIO	5406 ELONGATION %	5408 WIDTH REDUCTION %	5410 WALL THICKNESS REDUCTION %	5412 ANISOTROPY %
BEFORE	61.5	.62	17	26	47	.46
AFTER	74.7	.77	14	28	54	.44
CHANGE %	21.4	24	-18	7.7	14.5	-4.4

Fig. 54

5500

	5502 YIELD Ksi	5504 YIELD RATIO	5506 ELONGATION %	5508 WIDTH REDUCTION %	5510 WALL THICKNESS REDUCTION %	5512 ANISOTROPY %
BEFORE	61.9	.6	12	18	15	1.24
AFTER	105	.75	4	13	14	.94
CHANGE %	-70	-25	-67	27.8	6.7	75

Fig. 55

5600

	5602 YIELD Ksi	5604 YIELD RATIO	5606 ELONGATION %	5608 WIDTH REDUCTION %	5610 WALL THICKNESS REDUCTION %	5612 ANISOTROPY %
BEFORE	64.9	.78	20	47	59	.72
AFTER	71.5	.80	14	41	58	.60
CHANGE %	10.2	2.6	-30	-13	-1.7	-16.7

Fig. 56

5700

	5702 YIELD Ksi	5704 YIELD RATIO	5706 ELONGATION %	5708 WIDTH REDUCTION %	5710 WALL THICKNESS REDUCTION %	5712 ANISOTROPY %
BEFORE	46.9	.69	53	-52	55	.93
16% EXPANSION	65.9	.83	17	42	51	.78
24% EXPANSION	68.5	.83	5	44	54	.76
CHANGE %	46	-20	91	15	2	18

Fig. 57

5800

	5802 YIELD Ksi	5804 YIELD RATIO	5806 ELONGATION %	5808 WIDTH REDUCTION %	5810 WALL THICKNESS REDUCTION %	5812 ANISOTROPY %
BEFORE	47.7	.69	23	46	53	0.81
AFTER	65.9	.83	17	42	51	0.78
CHANGE %	38	20	11	9	4	4

Fig. 58

5900

	5902 YIELD Ksi	5904 YIELD RATIO	5906 ELONGATION %	5908 WIDTH REDUCTION %	5910 WALL THICKNESS REDUCTION %	5912 ANISOTROPY %
BEFORE	47.7	.69	23	46	53	0.81
AFTER	62.3	.71	12	40	52	.71
CHANGE %	31	14	48	13	2	12

Fig. 59

6000

	6002 YIELD Ksi	6004 YIELD RATIO	6006 ELONGATION %	6008 WIDTH REDUCTION %	6010 WALL THICKNESS REDUCTION %	6012 ANISOTROPY %
BEFORE	57.8	.71	44	43	46	.93
16% EXPANSION	74.4	.84	16	38	42	.87
24% EXPANSION	79.8	.86	20	36	42	.81
CHANGE %	38	-21	55	16	9	13

Fig. 60

6100

	6102 YIELD Ksi	6104 YIELD RATIO	6106 ELONGATION %	6108 WIDTH REDUCTION %	6110 WALL THICKNESS REDUCTION %	6112 ANISOTROPY %
BEFORE	56.4	.66	20	-39	-45	.83
AFTER	74.8	.83	14	33	41	.75
CHANGE %	33	26	30	15	9	10

Fig. 61

6200

	6202 YIELD Ksi	6204 YIELD RATIO	6206 ELONGATION %	6208 WIDTH REDUCTION %	6210 WALL THICKNESS REDUCTION %	6212 ANISOTROPY %
BEFORE	56.4	.66	20	-39	-45	.83
AFTER	79.6	.84	12	31	38	.79
CHANGE %	41	27	40	21	16	5

Fig. 62

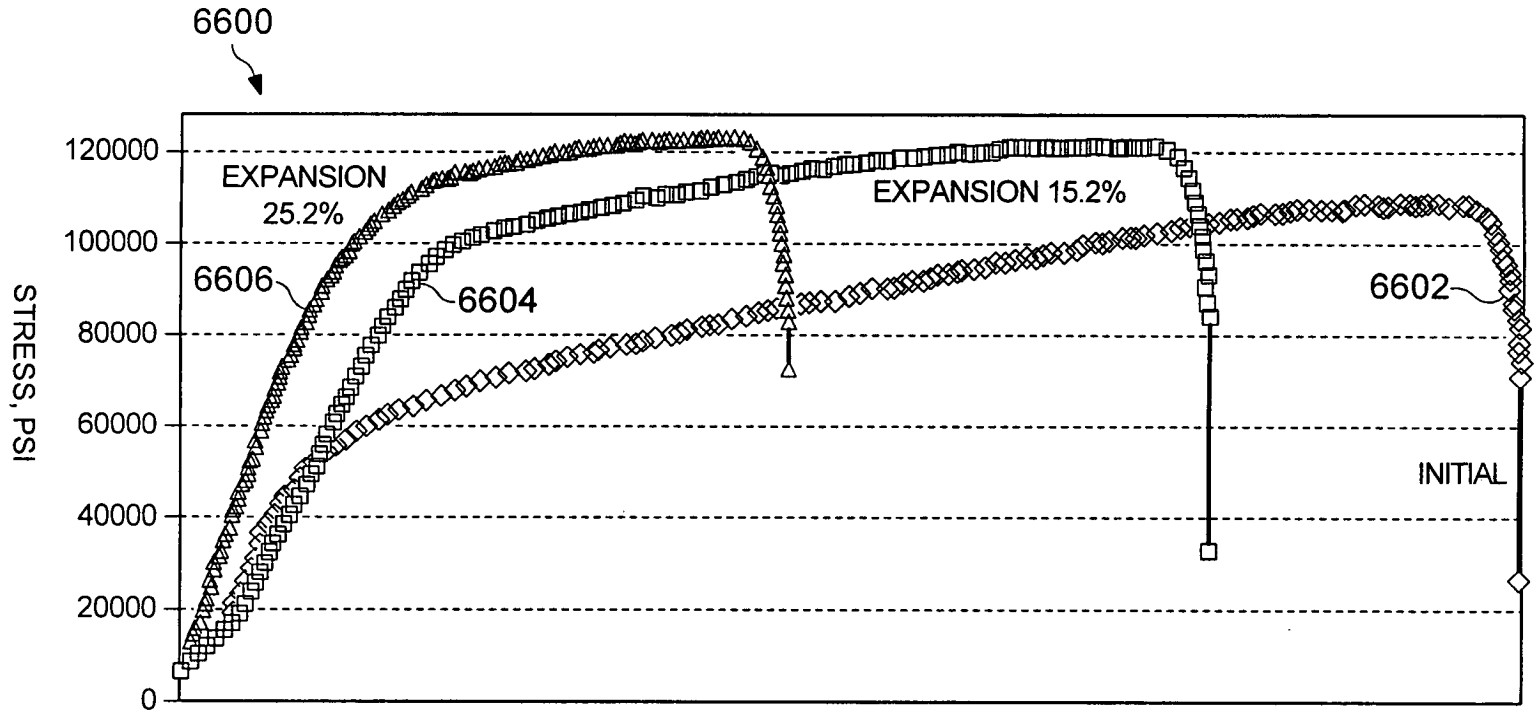
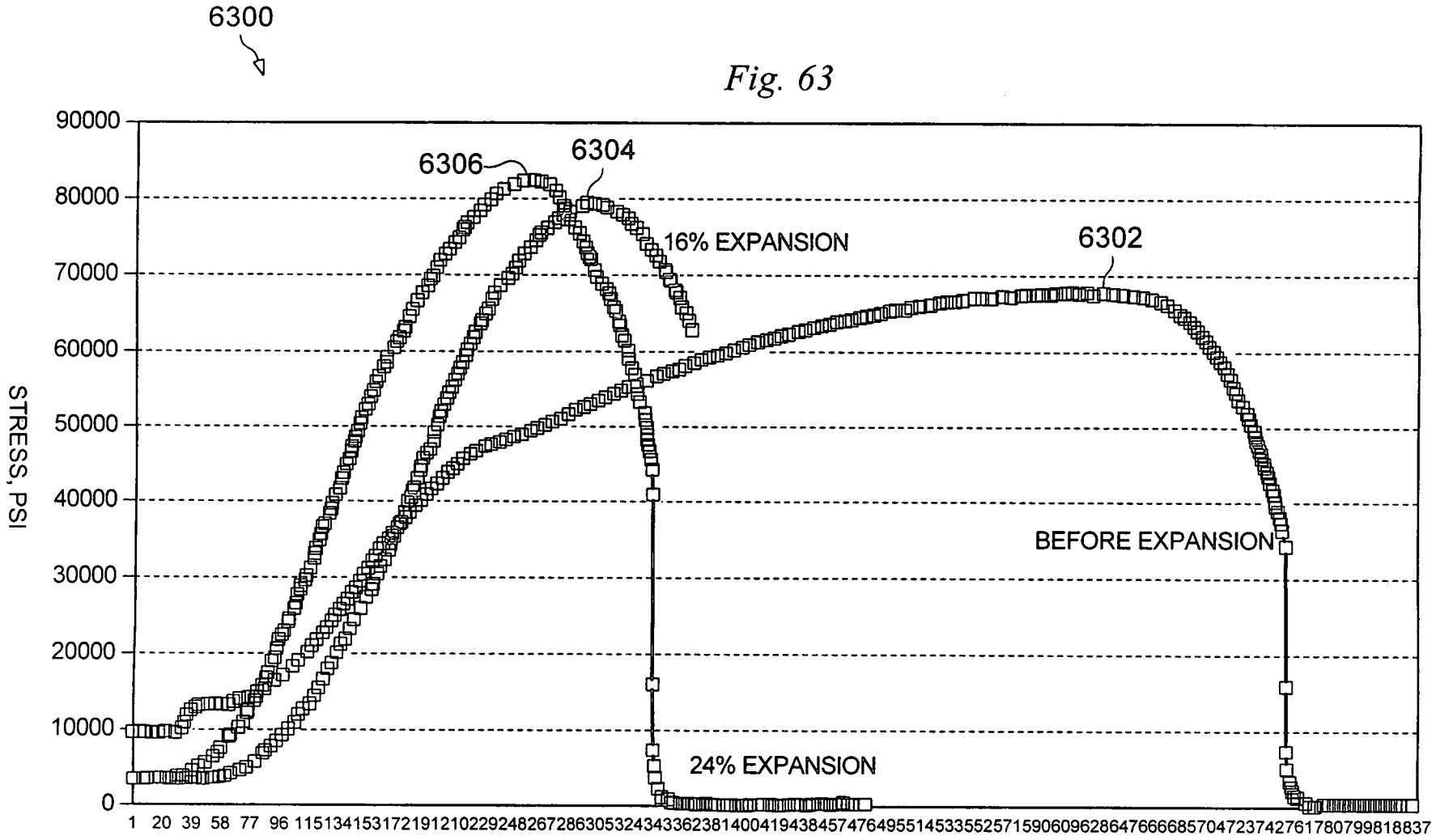


Fig. 66

Fig. 63


6300
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
STRESS, PSI
6306
6304
16% EXPANSION
6302
BEFORE EXPANSION
24% EXPANSION
1 20 39 58 77 96 115134153172191210229248267286305324343362381400419438457476495514533552571590609628647666685704723742761780799818837

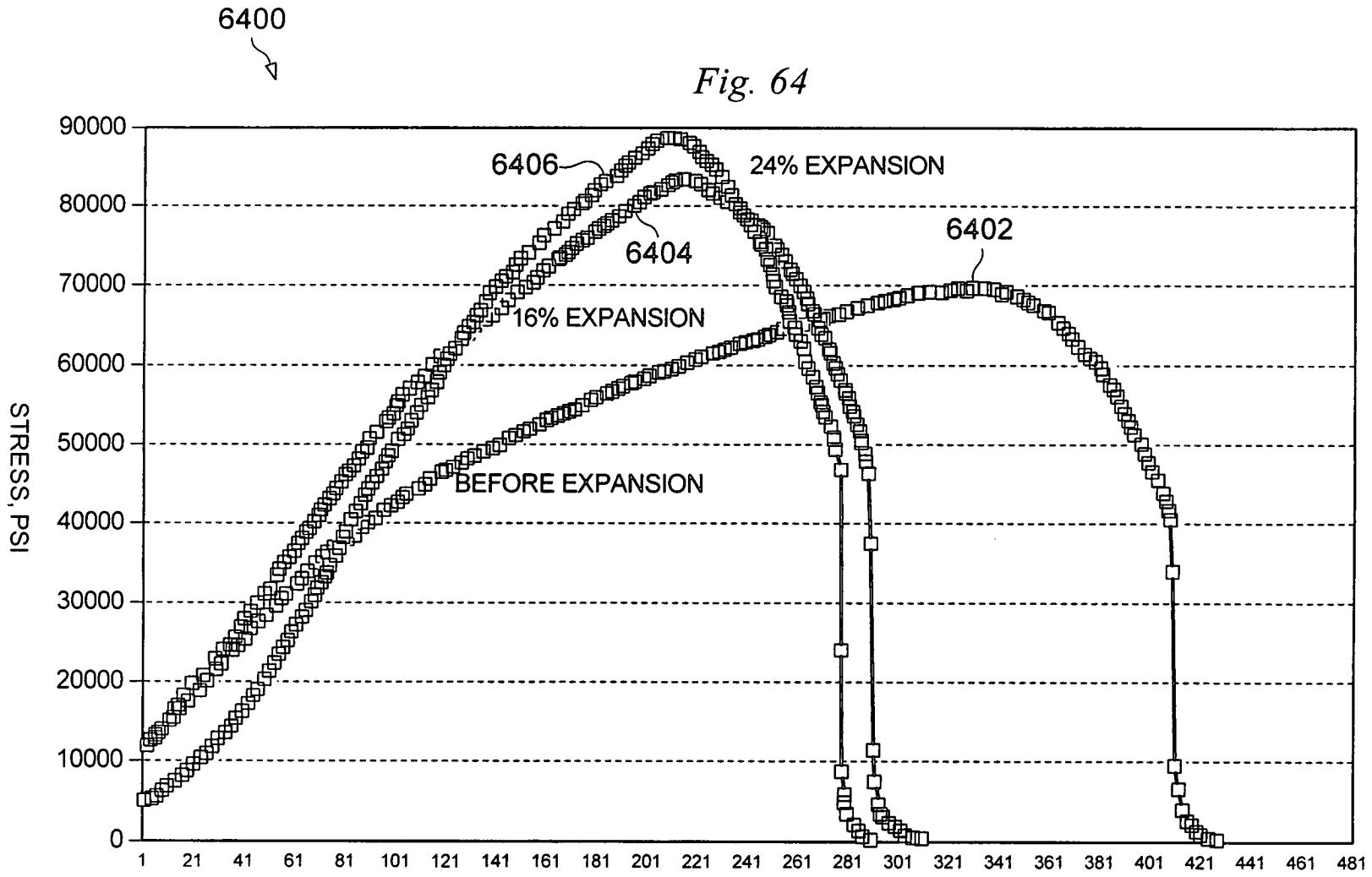
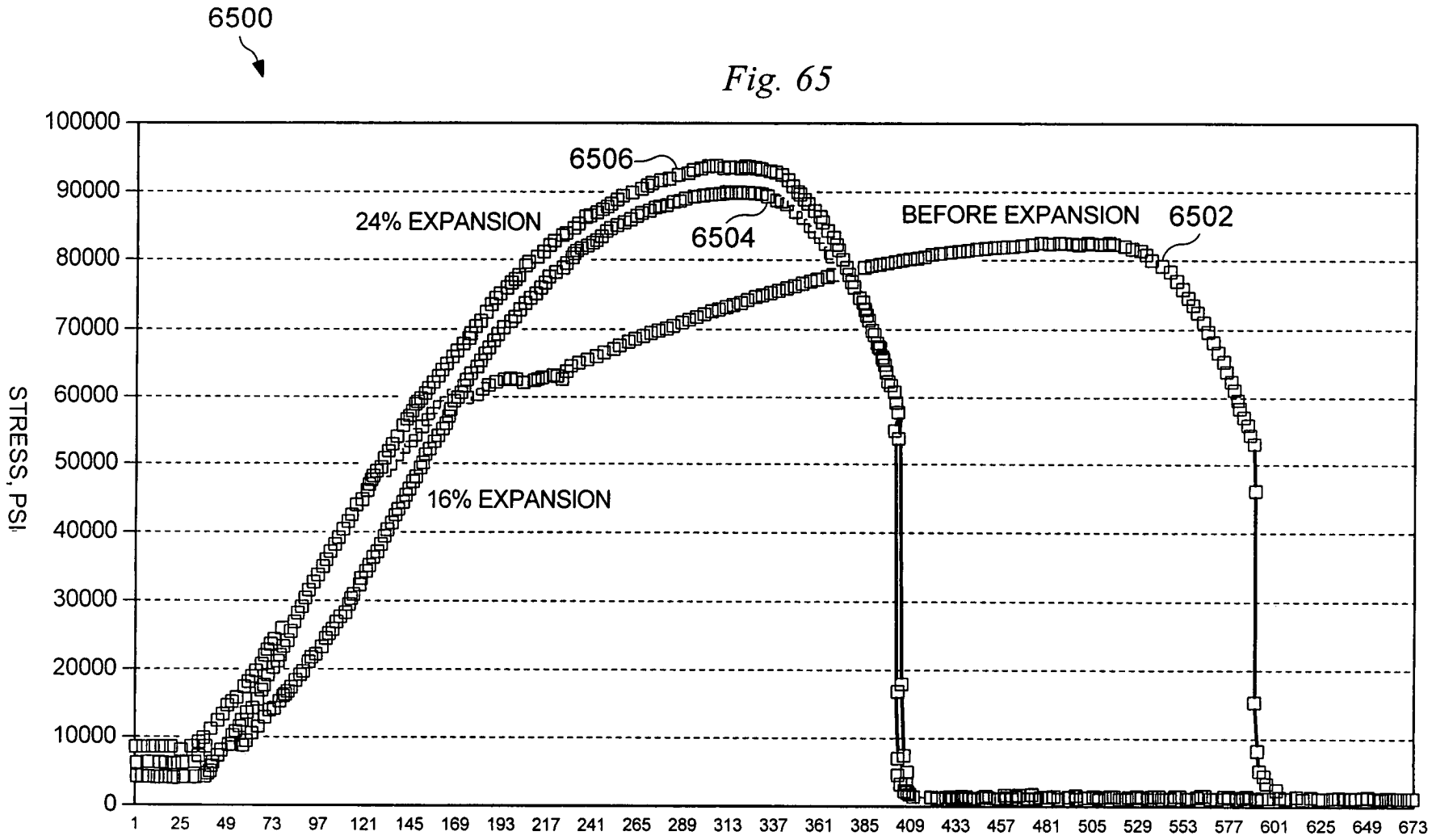

6400
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
STRESS, PSI
1
21
41
61
81
101
121
141
161
181
201
221
241
261
281
301
321
341
361
381
401
421
441
461
481
6406
24% EXPANSION
6404
6402
16% EXPANSION
BEFORE EXPANSION

Fig. 64

Fig. 65


6500
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
STRESS, PSI
6506
24% EXPANSION
6504
BEFORE EXPANSION
6502
16% EXPANSION
1
25
49
73
97
121
145
169
193
217
241
265
289
313
337
361
385
409
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457
481
505
529
553
577
601
625
649
673

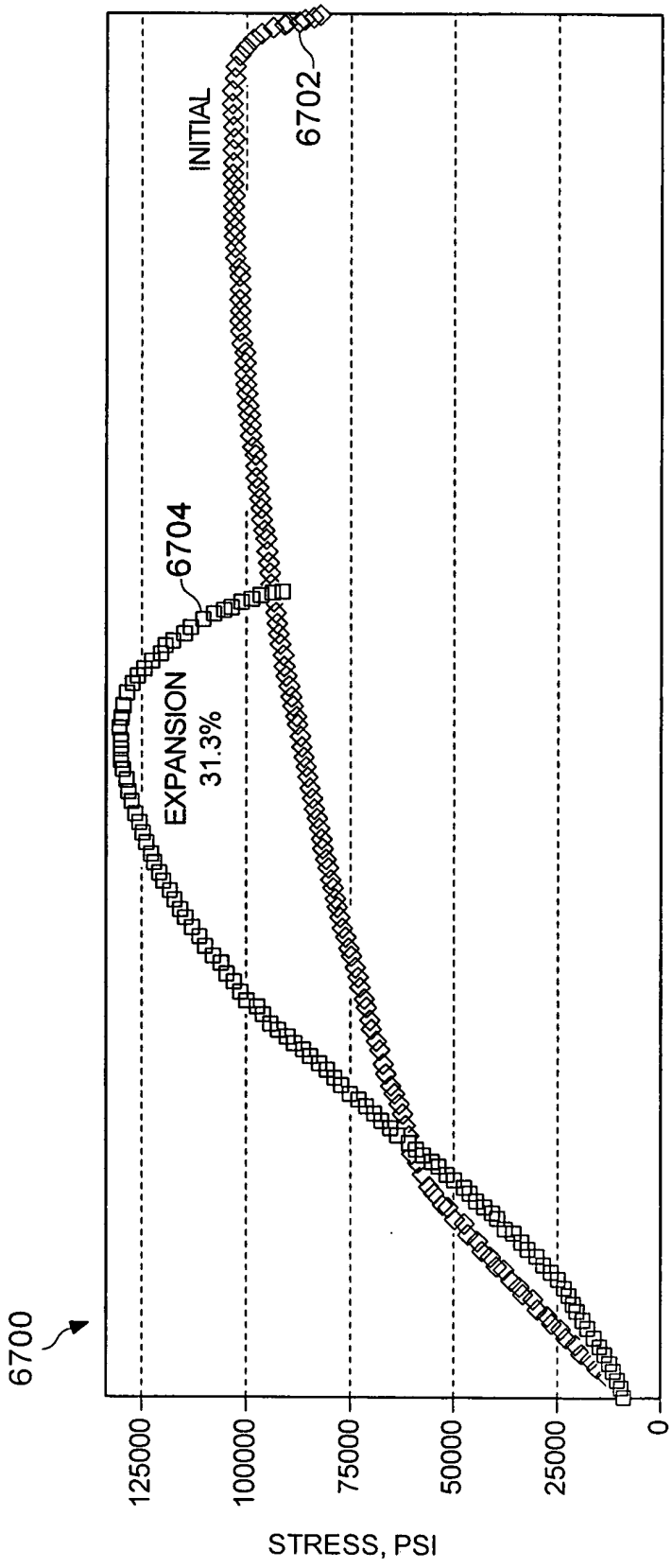
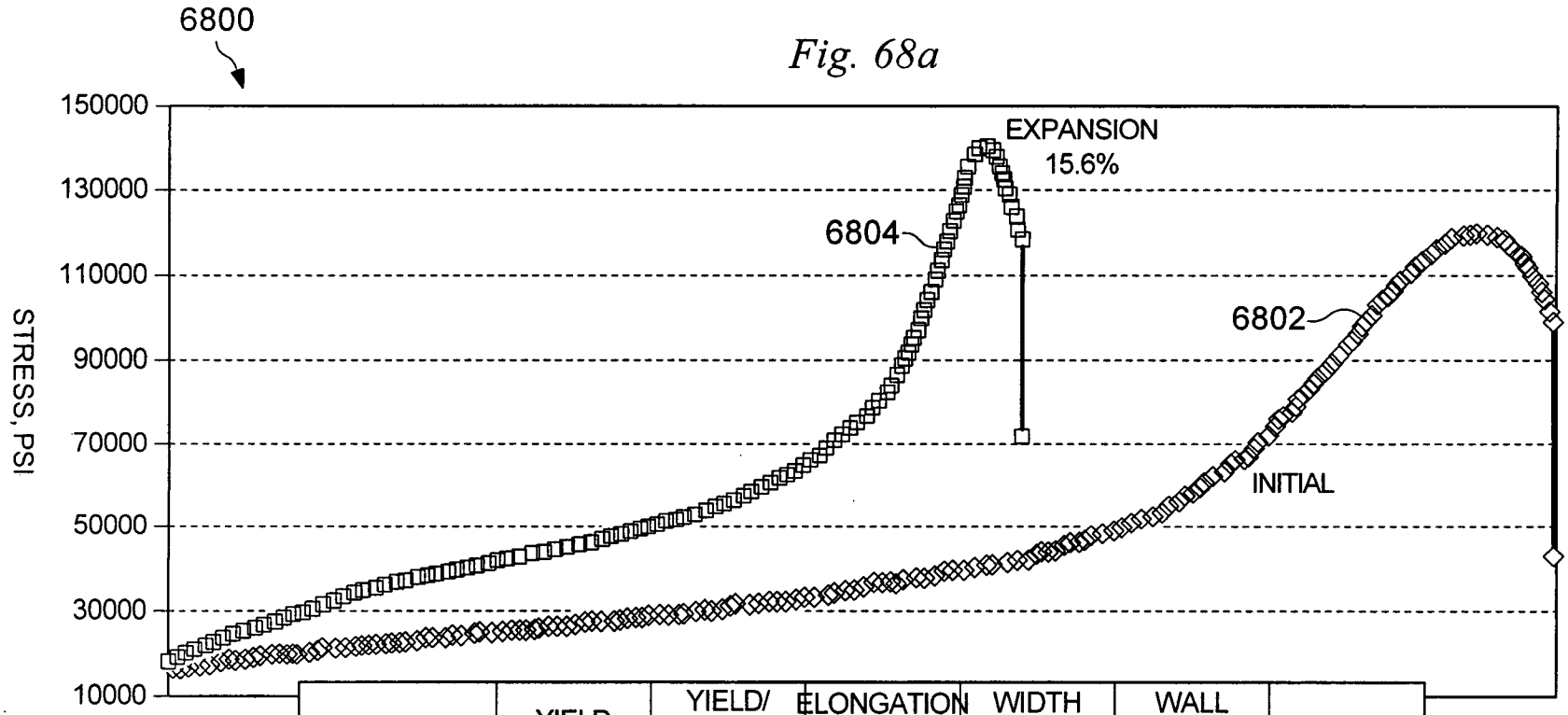

6700
125000
100000
75000
50000
25000
0
STRESS, PSI
INITIAL
6702
6704
EXPANSION
31.3%

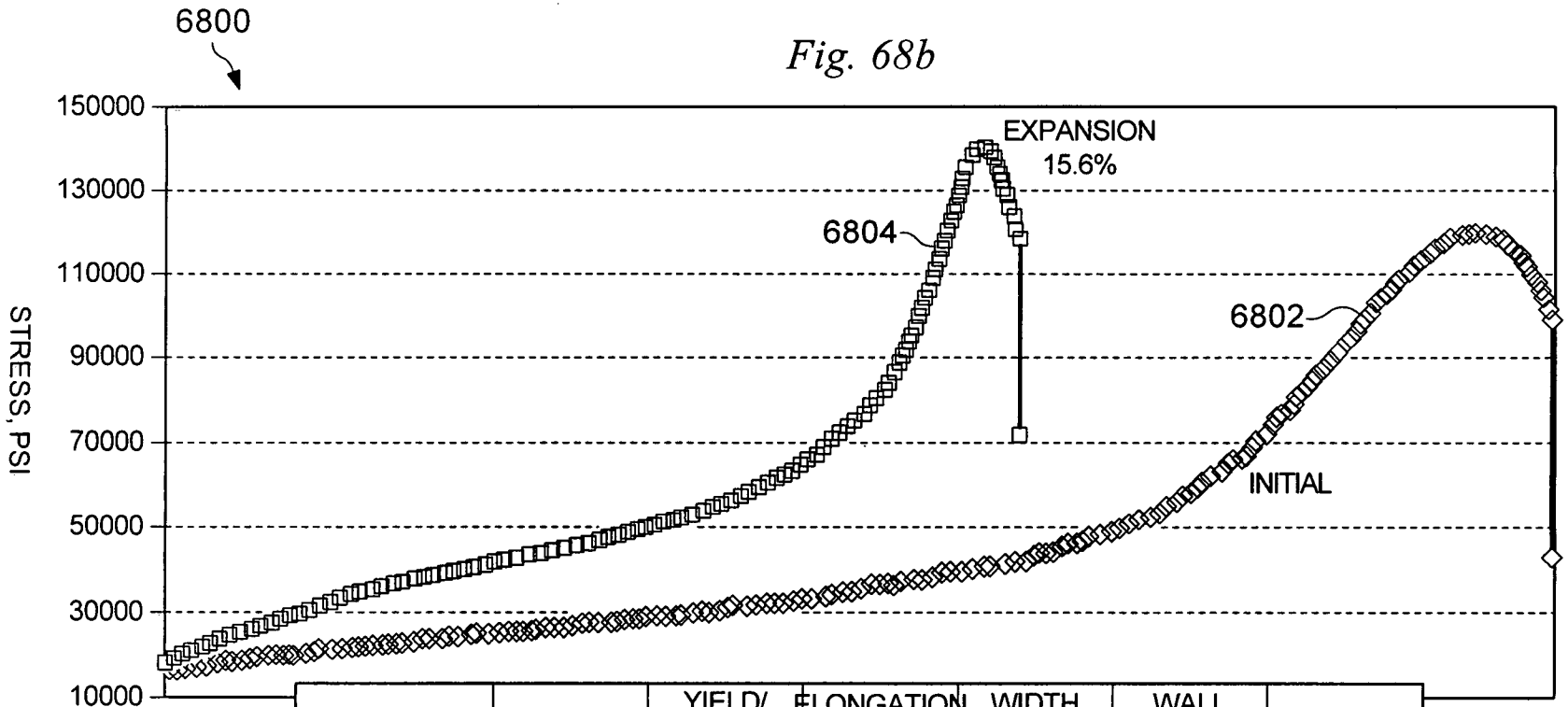
Fig. 67

Fig. 68a



MATERIAL	YIELD Ksi	YIELD/ TENSILE RATIO	ELONGATION LONGITUDINAL %	WIDTH REDUCTION %	WALL THICKNESS REDUCTION %	ANISOTROPY
TARGET	76.8	0.82	16	32	45	0.65
HISTORY	50.7	0.44	12	18	15	1.24

Fig. 68b

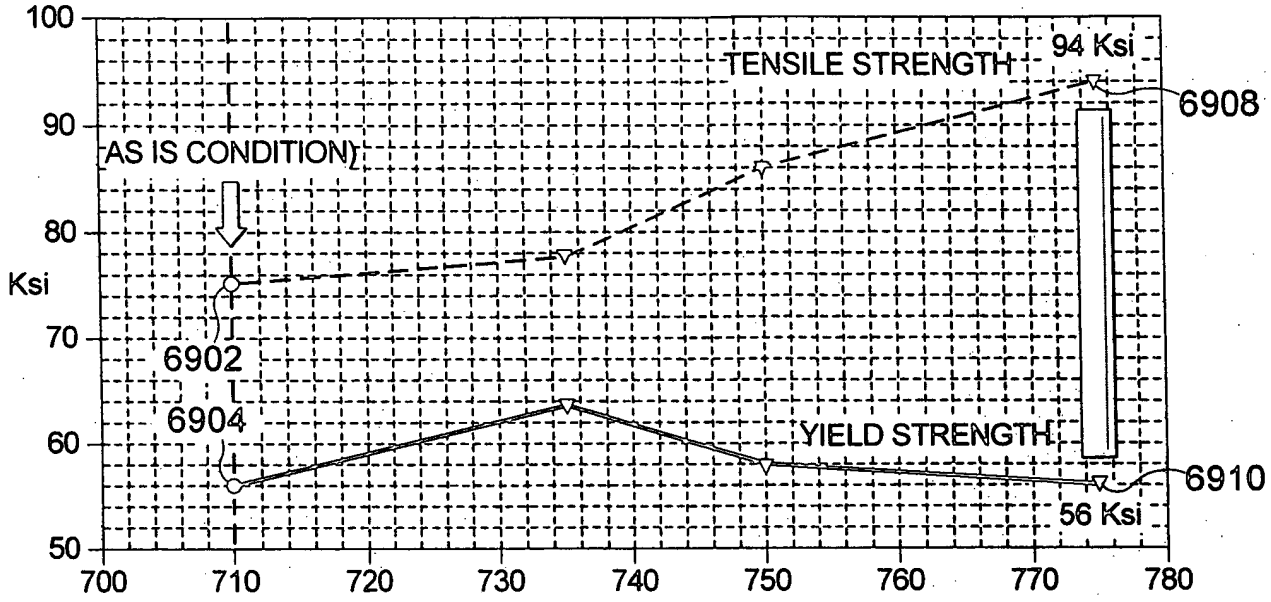


MATERIAL	YIELD Ksi	YIELD/ TENSILE RATIO	ELONGATION LONGITUDINAL %	WIDTH REDUCTION %	WALL THICKNESS REDUCTION %	ANISOTROPY
TARGET	76.8	0.82	16	32	45	0.65
HISTORY	50.7	0.44	12	18	15	1.24

6806

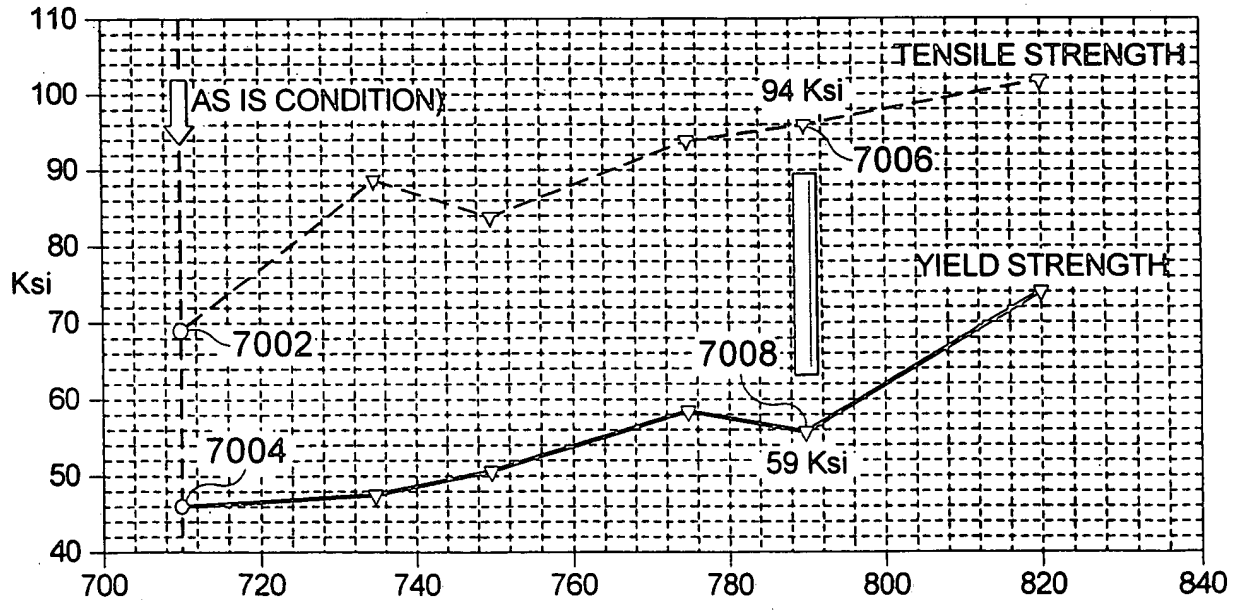
6900

Fig. 69



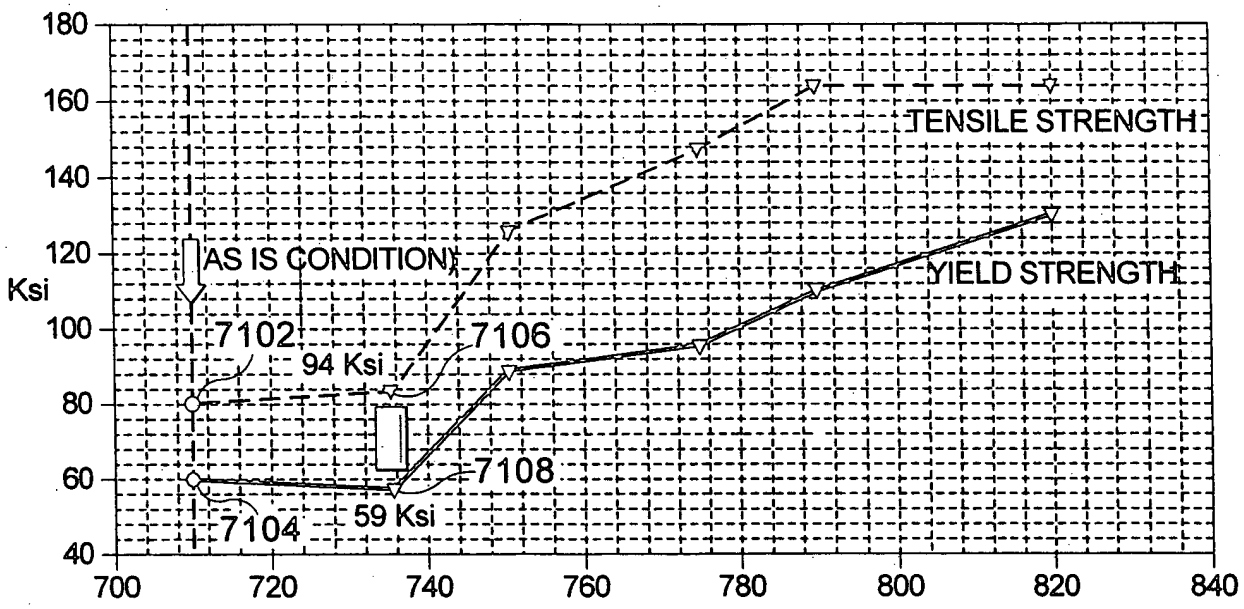
7000

Fig. 70



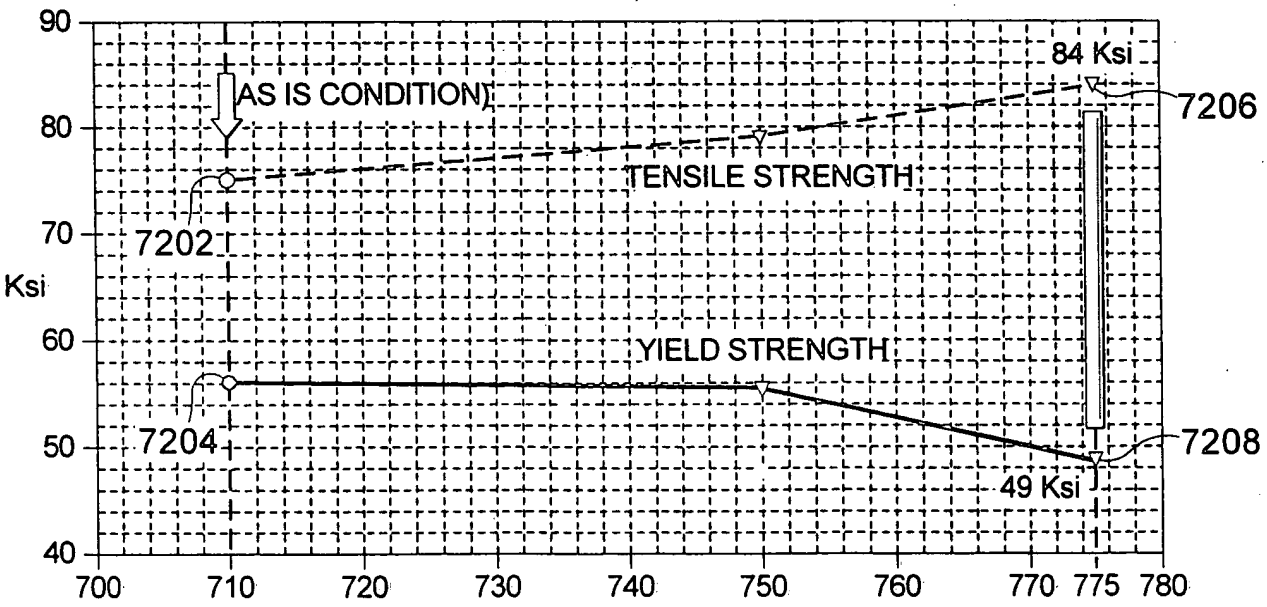
7100

Fig. 71



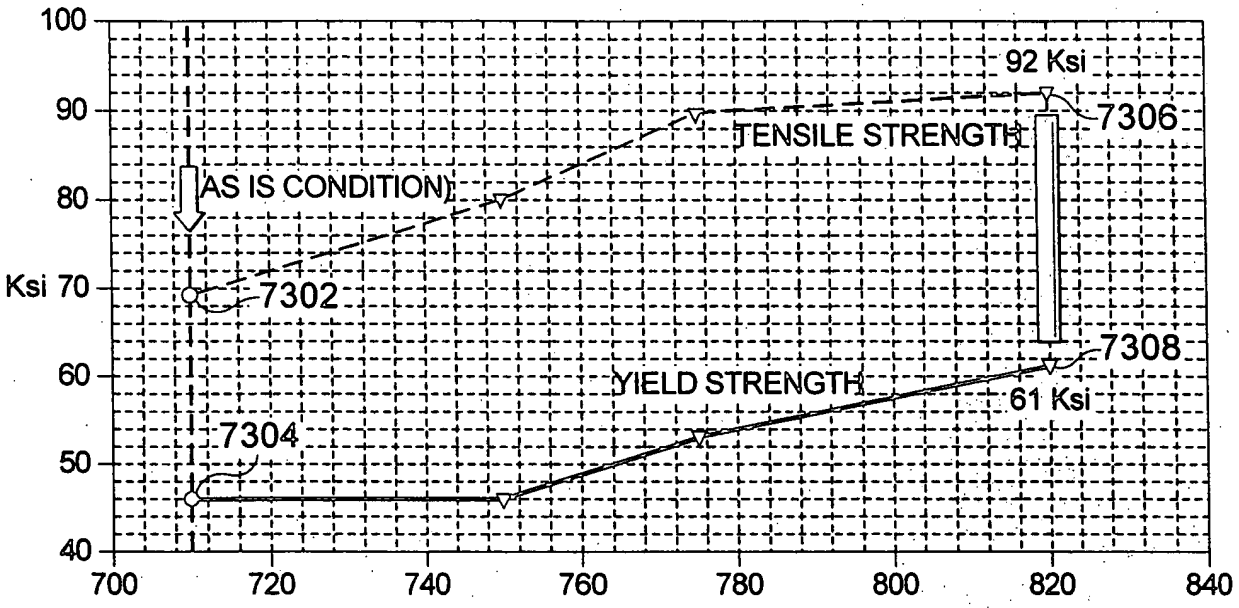
7200

Fig. 72



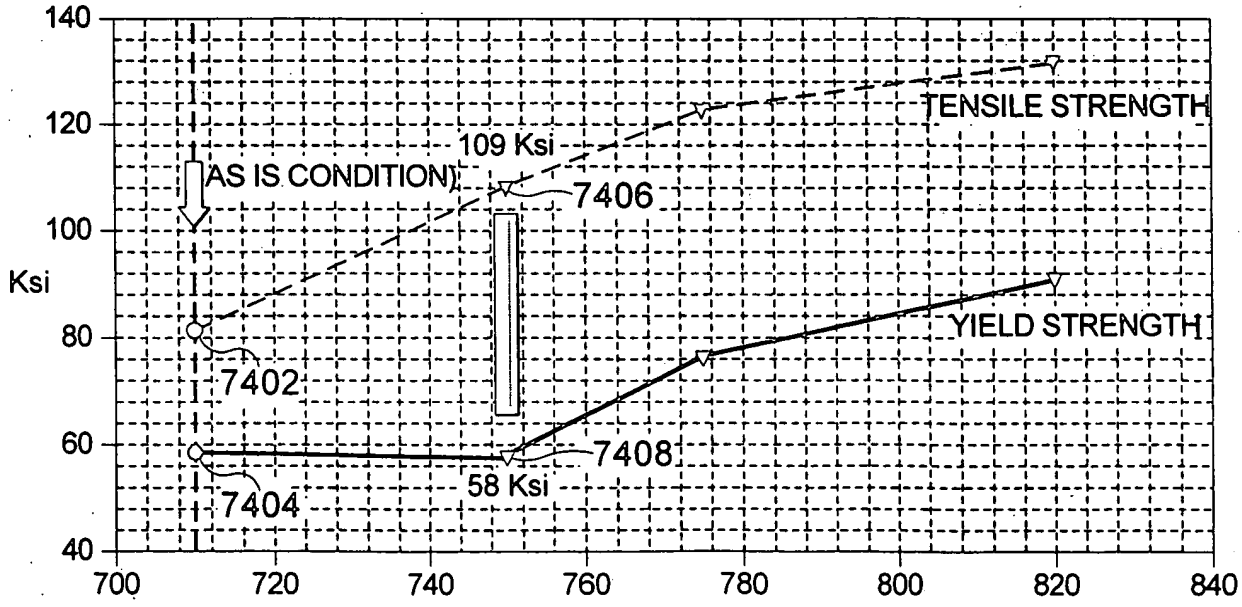
7300

Fig. 73



7400

Fig. 74



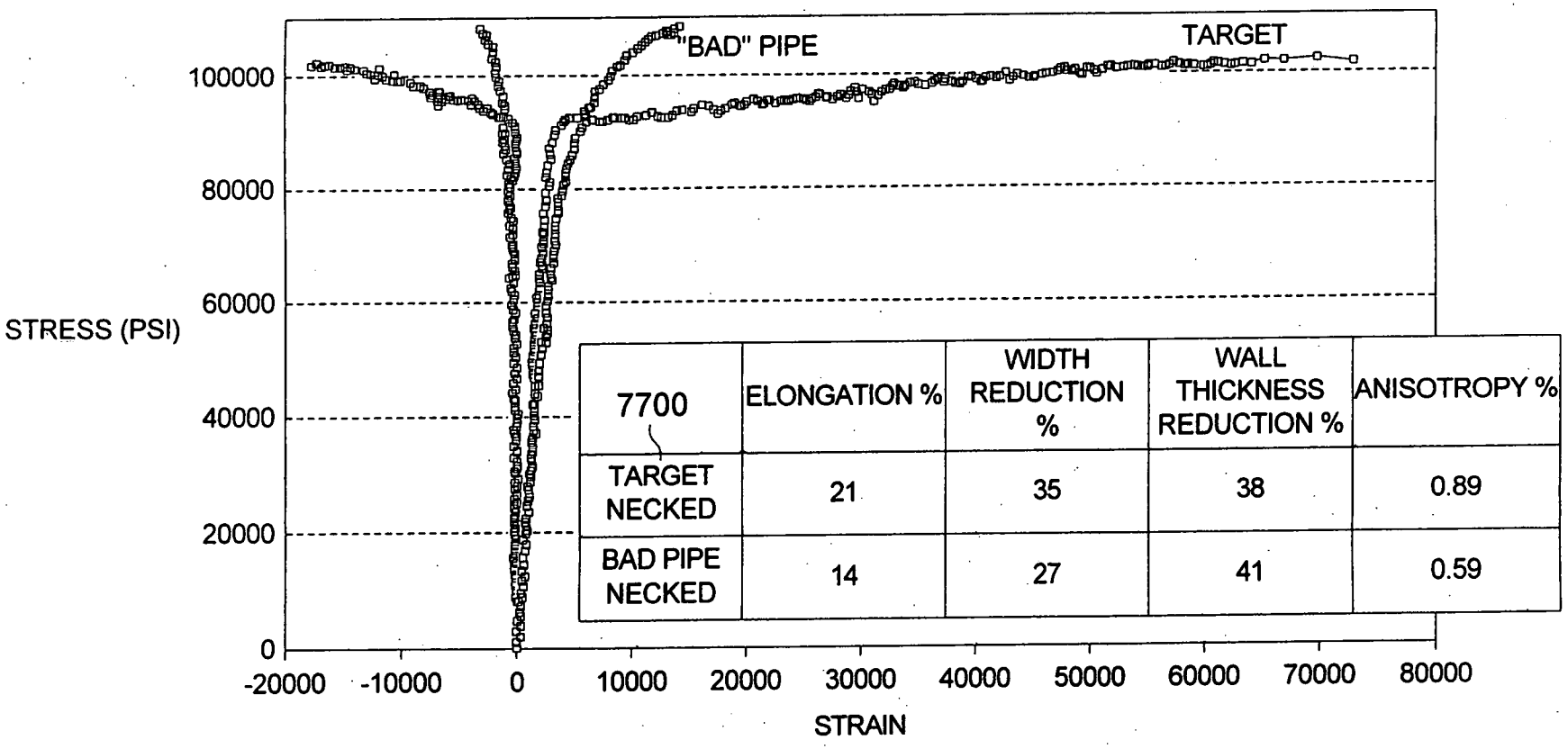
	7506	7508	7510	7512	7514	7516
	MATERIAL	YIELD Ksi	YIELD/ TENSILE RATIO	ELONGATION LONGITUDINAL %	WIDTH REDUCTION %	WALL THICKNESS REDUCTION %	ANISOTROPY
7500	TARGET	80.18	0.857	14.75*	38.3	43.0	0.868
7502	QUENCH AND TEMPER PIPE-1	81.25	0.829	14.88*	37.8	43.25	0.830
7504	QUENCH AND TEMPER PIPE-2	78.77	0.822	15.90*	44.0	43.33	1.03

Fig. 75

	7504	7506	7508	7510	7512	7514
	MATERIAL	YIELD Ksi	YIELD/ TENSILE RATIO	ELONGATION LONGITUDINAL %	WIDTH REDUCTION %	WALL THICKNESS REDUCTION %	ANISOTROPY
7500	TARGET	80.18	0.857	14.75*	38.3	43.0	0.868
7502	QUENCH AND TEMPER PIPE	80.19	0.826	15.25*	40.4	43.3	0.915

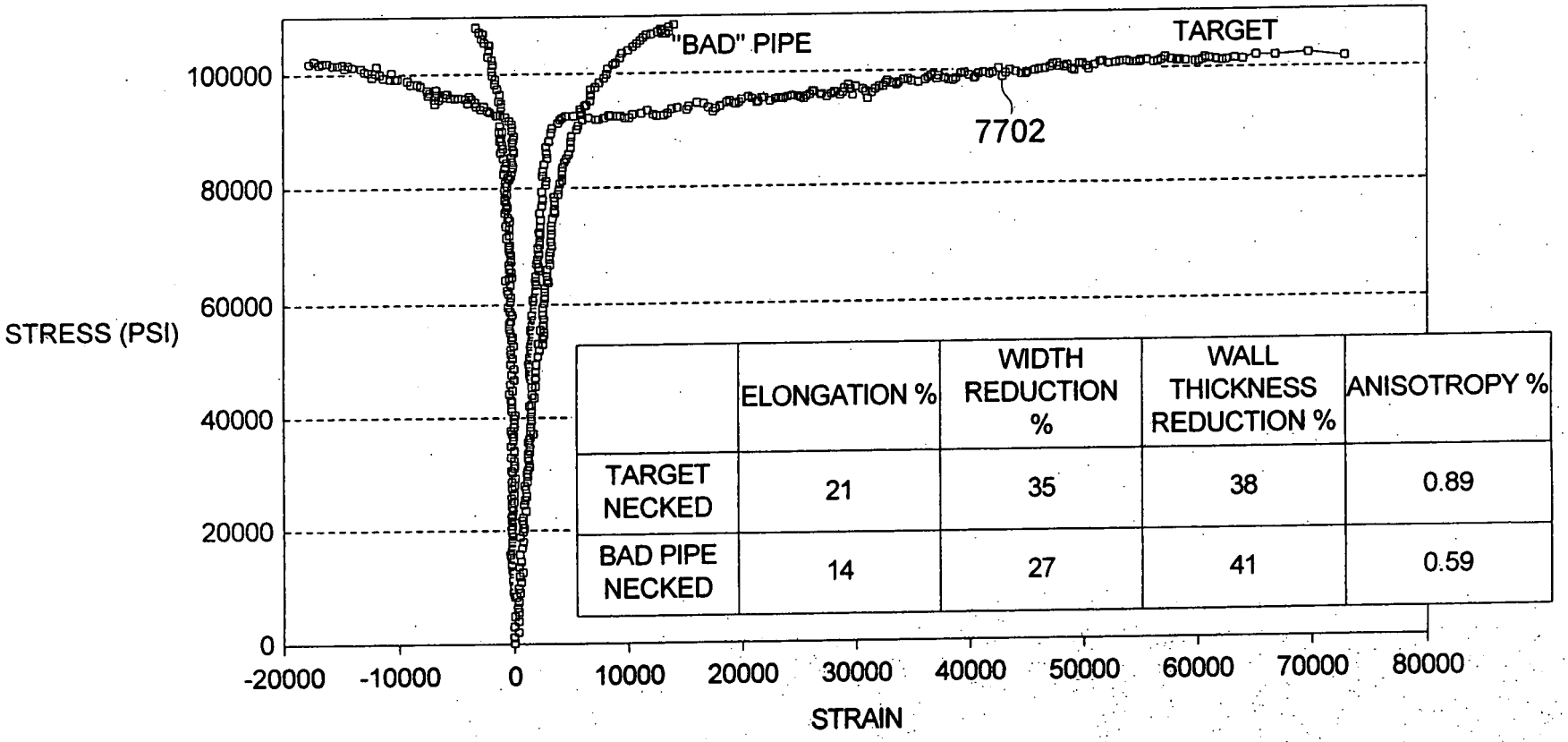
Fig. 76

Fig. 77a



7700	ELONGATION %	WIDTH REDUCTION %	WALL THICKNESS REDUCTION %	ANISOTROPY %
TARGET NECKED	21	35	38	0.89
BAD PIPE NECKED	14	27	41	0.59

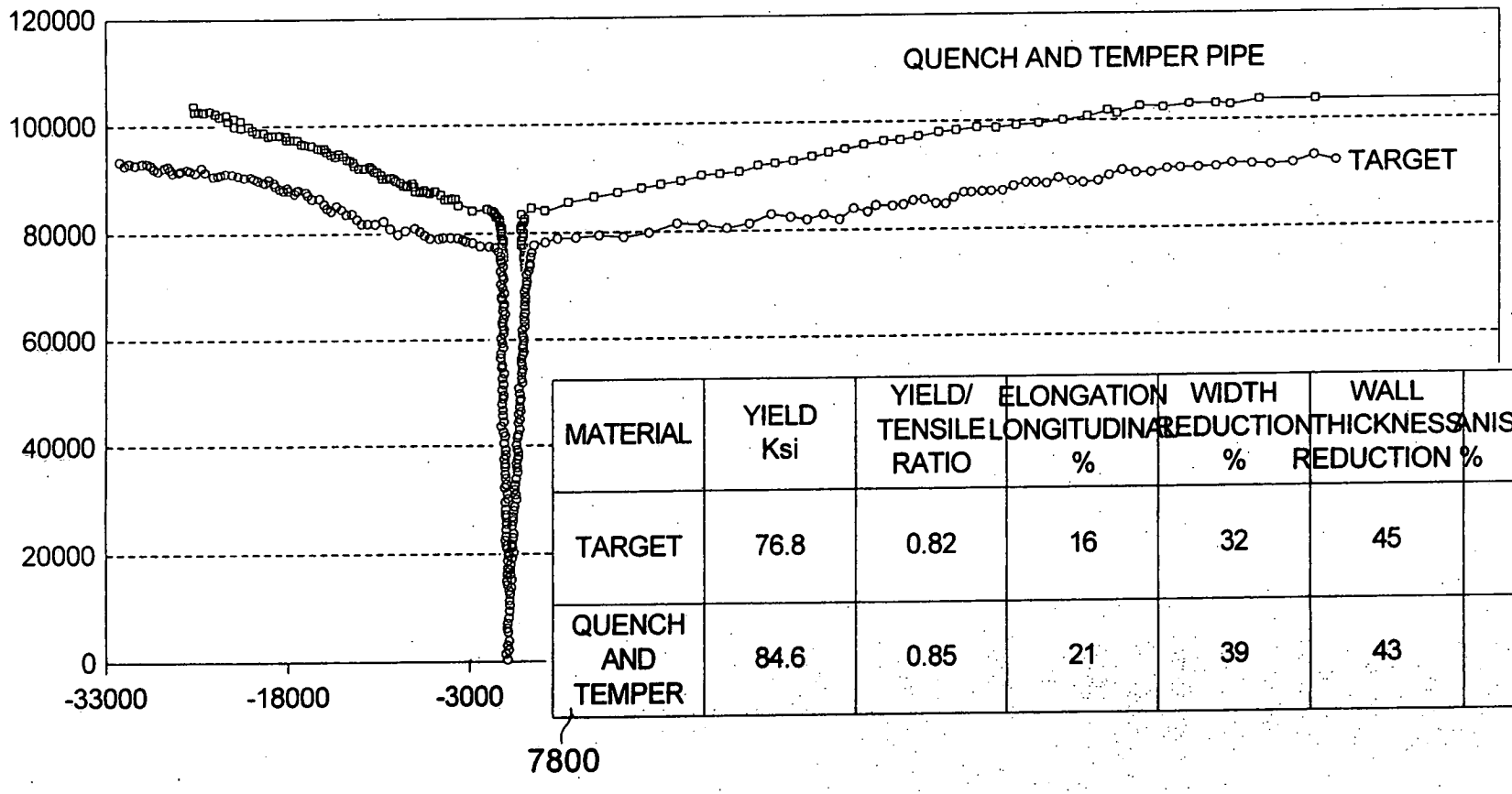
Fig. 77b



	ELONGATION %	WIDTH REDUCTION %	WALL THICKNESS REDUCTION %	ANISOTROPY %
TARGET NECKED	21	35	38	0.89
BAD PIPE NECKED	14	27	41	0.59

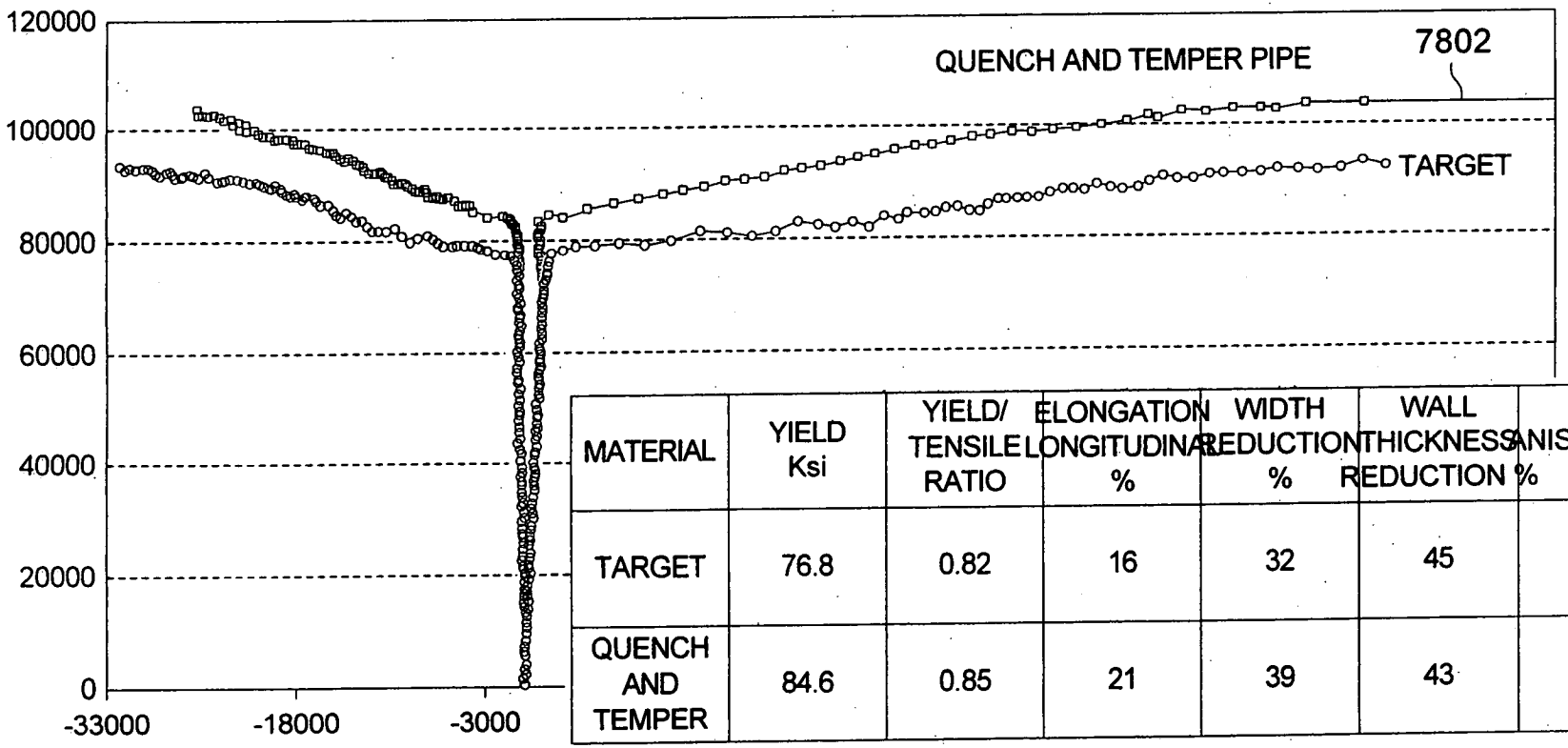
7179

Fig. 78a



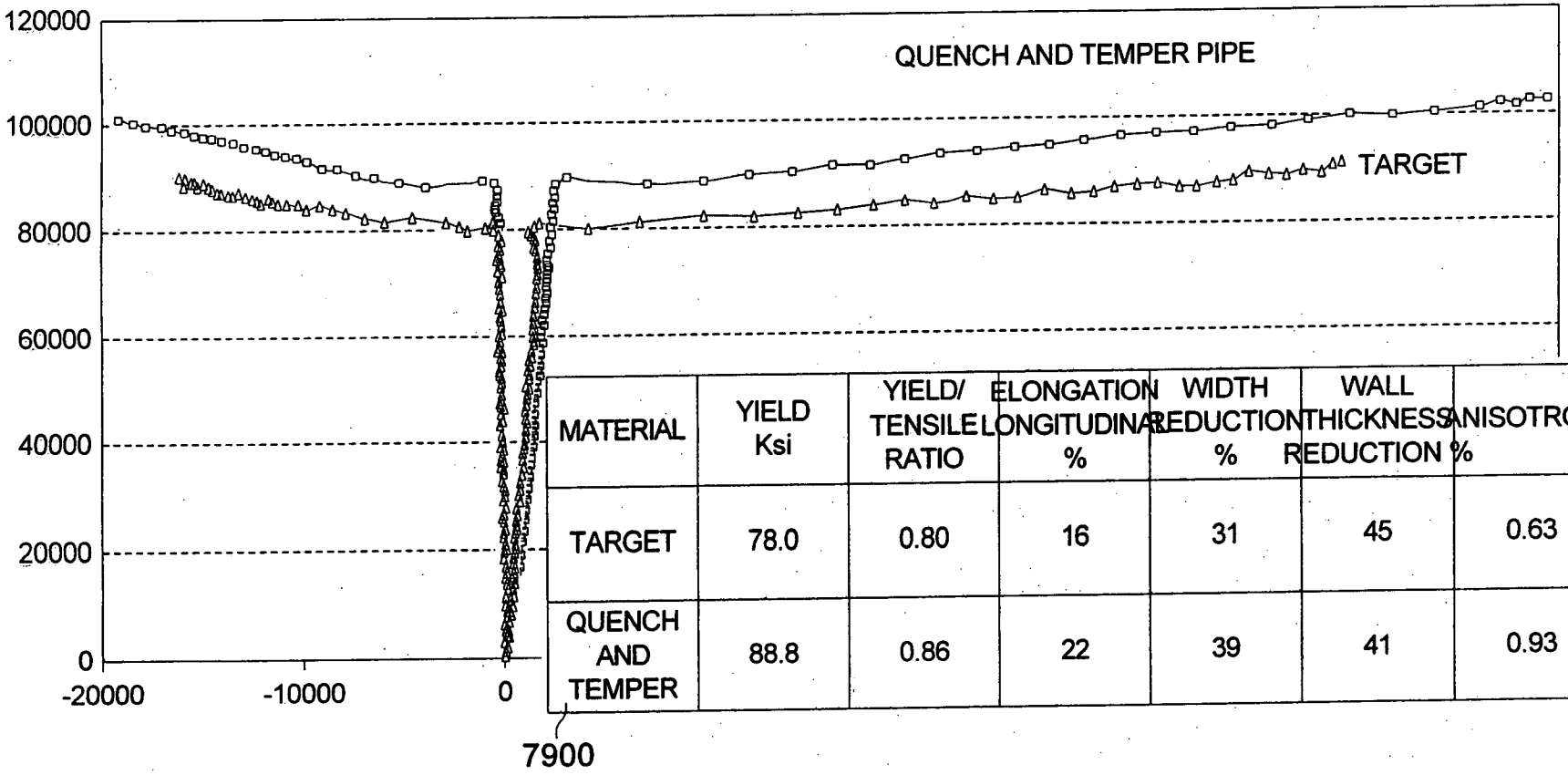
MATERIAL	YIELD Ksi	YIELD/ TENSILE RATIO	ELONGATION LONGITUDINAL %	WIDTH REDUCTION %	WALL THICKNESS REDUCTION %	ANISOTROPY
TARGET	76.8	0.82	16	32	45	0.65
QUENCH AND TEMPER	84.6	0.85	21	39	43	0.88

Fig. 78b



MATERIAL	YIELD Ksi	YIELD/ TENSILE RATIO	ELONGATION LONGITUDINAL %	WIDTH REDUCTION %	WALL THICKNESS REDUCTION %	ANISOTROPY
TARGET	76.8	0.82	16	32	45	0.65
QUENCH AND TEMPER	84.6	0.85	21	39	43	0.88

Fig. 79a



MATERIAL	YIELD Ksi	YIELD/ TENSILE RATIO	ELONGATION LONGITUDINAL %	WIDTH REDUCTION %	WALL THICKNESS REDUCTION %	ANISOTROPY
TARGET	78.0	0.80	16	31	45	0.63
QUENCH AND TEMPER	88.8	0.86	22	39	41	0.93

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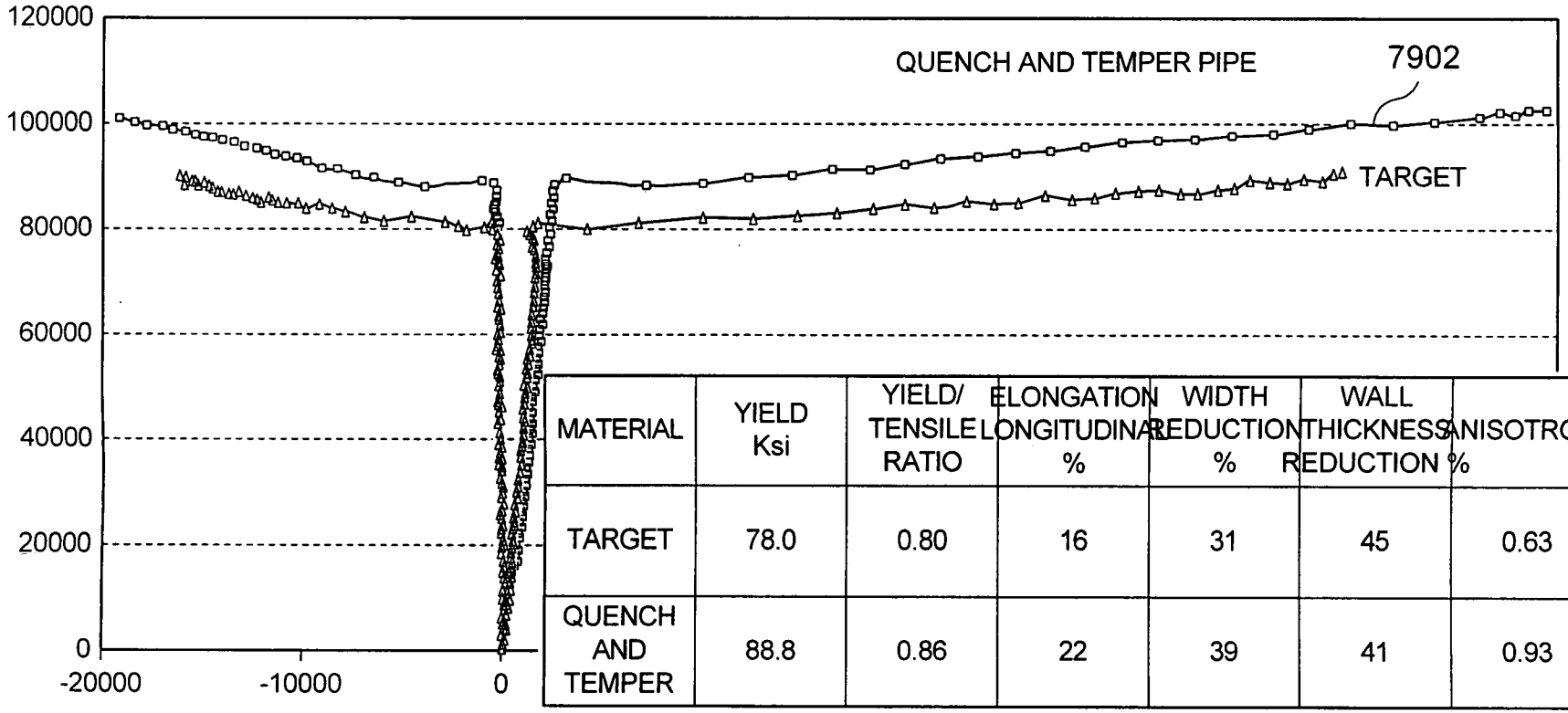
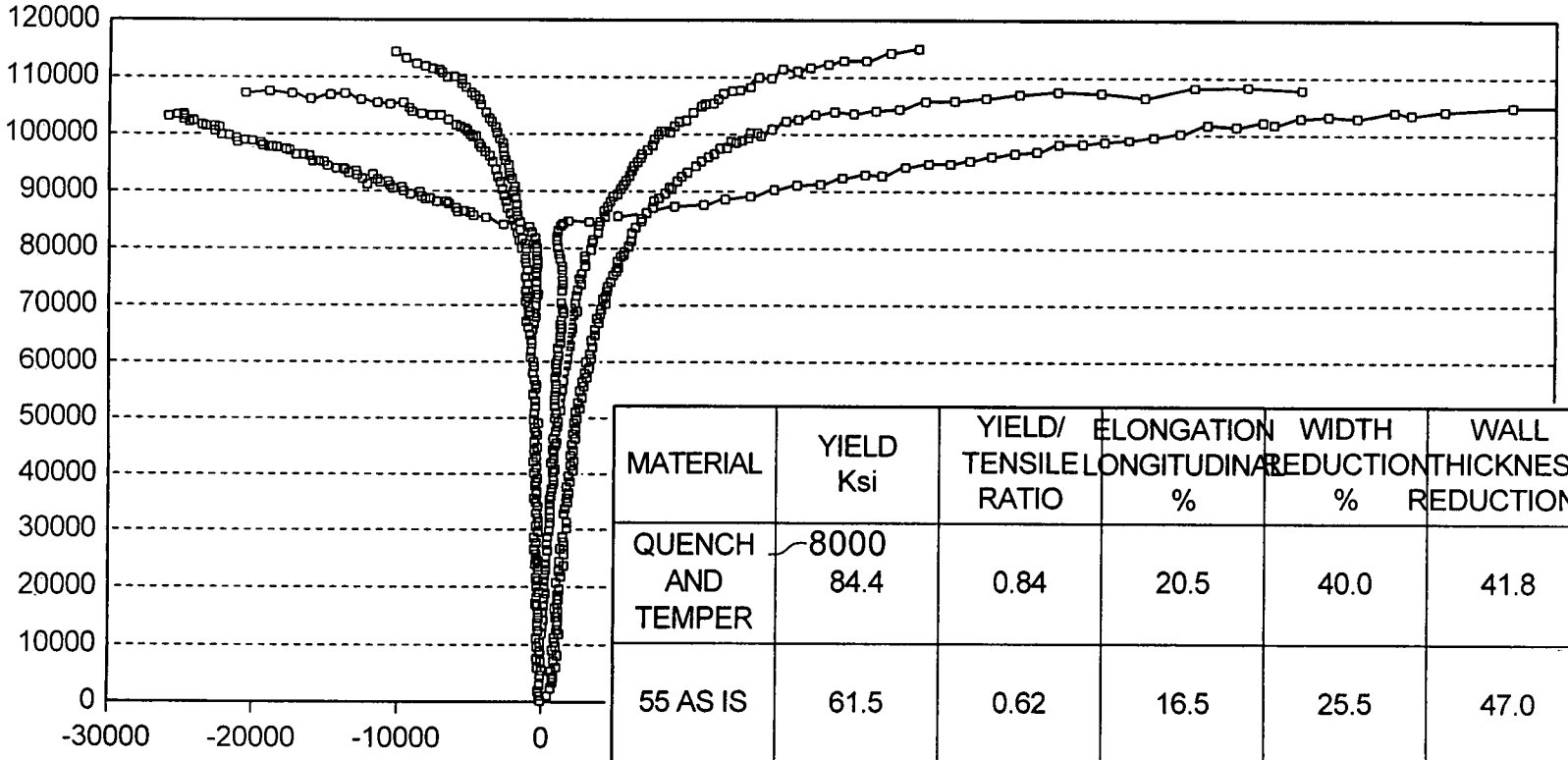
Fig. 79b



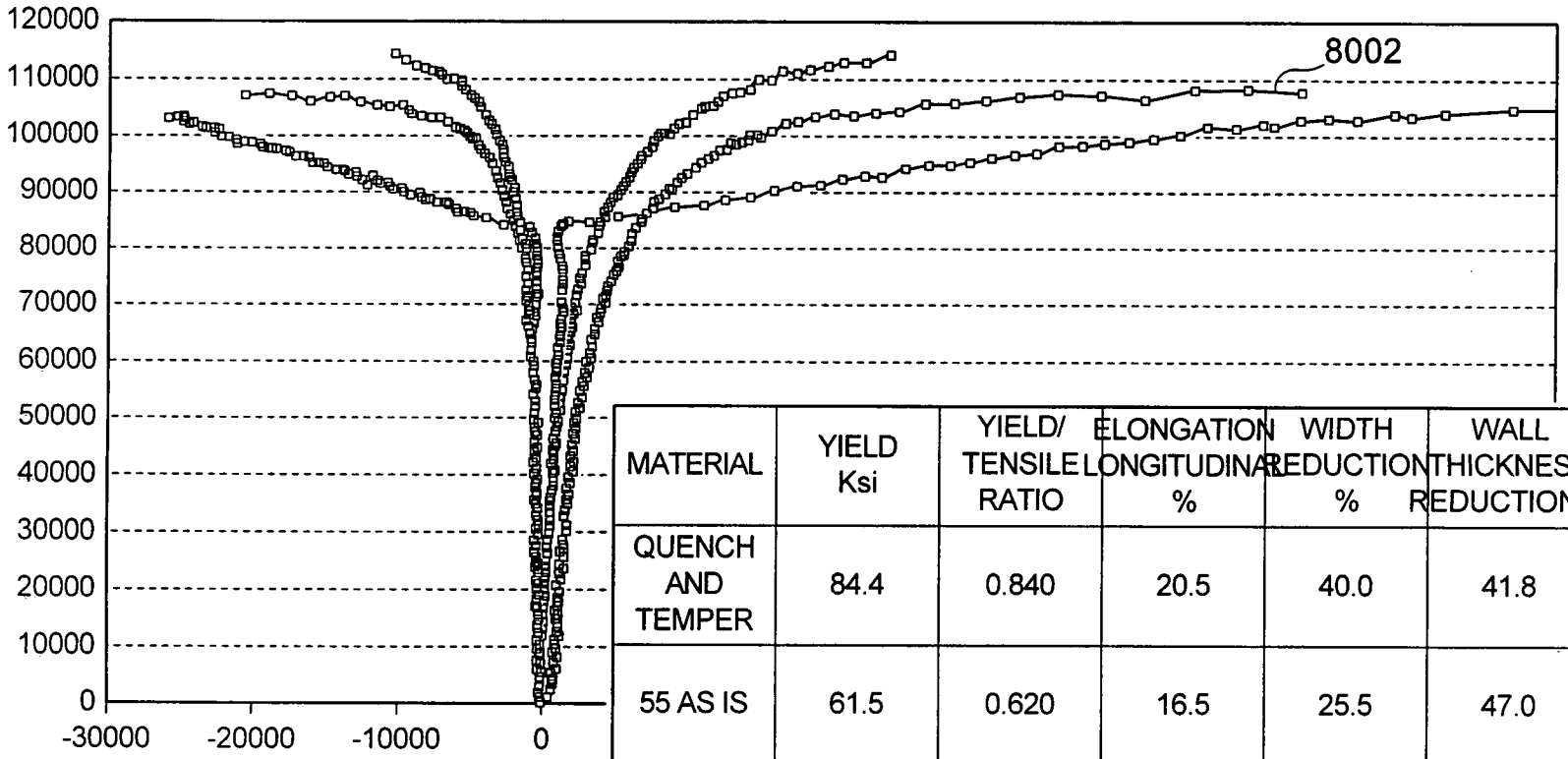
MATERIAL	YIELD Ksi	YIELD/ TENSILE RATIO	ELONGATION LONGITUDINAL %	WIDTH REDUCTION %	WALL THICKNESS REDUCTION %	ANISOTROPY
TARGET	78.0	0.80	16	31	45	0.63
QUENCH AND TEMPER	88.8	0.86	22	39	41	0.93

Fig. 80a



MATERIAL	YIELD Ksi	YIELD/ TENSILE RATIO	ELONGATION LONGITUDINAL %	WIDTH REDUCTION %	WALL THICKNESS REDUCTION %	ANISOTROPY
QUENCH AND TEMPER	8000 84.4	0.84	20.5	40.0	41.8	0.935
55 AS IS	61.5	0.62	16.5	25.5	47.0	0.460
80 AS IS	73.7	0.67	13.5	20.4	37.5	0.480

Fig. 80b



MATERIAL	YIELD Ksi	YIELD/ TENSILE RATIO	ELONGATION LONGITUDINAL %	WIDTH REDUCTION %	WALL THICKNESS REDUCTION %	ANISOTROPY
QUENCH AND TEMPER	84.4	0.840	20.5	40.0	41.8	0.935
55 AS IS	61.5	0.620	16.5	25.5	47.0	0.460
80 AS IS	73.7	0.670	13.5	20.4	37.5	0.480

Fig. 81

	SAMPLE	YIELD	Y/U	ELONGATION	WIDTH REDUCTION	WALL THICKNESS REDUCTION	ANISOTROPY	TECHNOLOGY
8100	40045	80.1	.72	35	35	33	.92	HOT STRETCH, REDUCED (1950), ROTARY STRAIGHTENED
8102	4-100	89.7	.88	25	22	20	1.1	NORMALIZED (1850), COLD DRAWN, ANNEALED (1050), ROTARY STRAIGHTENED
8104	5-790	88.1	.87	16	24	30	.76	HOT STRETCH, REDUCED (1950) COLD DRAWN, ANNEALED, ROTARY STRAIGHTENED
8106	40513	47.7	.73	38	43	49	.83	HOT STRETCH, REDUCED (1850), ROTARY STRAIGHTENED
8108	40514	45.5	.69	40	50	53	.93	HOT REDUCED (1850), COLD SIZED, ROTARY STRAIGHTENED
8110	40241	52.7	.85	49	49	46	1.1	HOT STRETCH, REDUCED (1850), ROTARY STRAIGHTENED

Fig. 82

	MATERIAL	ABSORBED ENERGY^ LONGITUDINAL	TRANSVERSE	WELD	FLARE EXPANSION %
	TARGET	80	60	60	45
8200	QUENCH AND TEMPER	125	59	176	42
8202	QUENCH AND TEMPER	145	59	174	52
	AS IS, 55 GRADE	100	40	70	32*
	AS IS, 80 GRADE	50	30	4	30*